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ABSTRACT

The aim of good lighting is to not only provide proper illumination for building users to perform their allotted tasks, but also to pleasantly enhance the indoor environment. This document guides architects and engineers through the process of lighting design in the context of the recommended constructional standards for schools and the various types of spaces and activities found in schools. It identifies the determining factors of good lighting design as architectural integration, task and activity lighting, visual amenity, cost, maintenance, and energy efficiency. Further, it describes the calculation methods and design tools that can be used at the early stages of a project and shows, using theory and examples, how to achieve a synthesis between daylight and electric light. Appendices present school premises regulations and Department for Education and Employment Constructional Standards for new school buildings, information on lighting and health, and details concerning various lamps, controlling gear, luminary performance ranges, lighting controls, disposal of used lamps, and examples of lighting design strategies. A glossary concludes the book. (Contains 35 references.) (GR)

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BUILDING BULLETIN 90

Lighting Design for Schools

Architects and Building Branch

London: The Stationery Office

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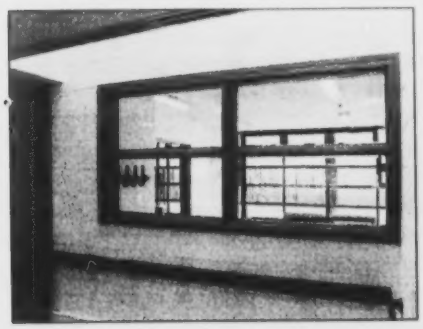
Section 1: Introduction

The best school environments give an impression of liveliness, with attractive spaces and a general feeling of pleasantness which it is difficult to define. There can be no doubt that in these cases the surroundings contribute to the happiness and well-being of teachers and pupils, and that lighting plays a significant if not the leading role. Lighting (both natural and electric) will be recognised as an essential contribution if it stems from and encourages the fulfilment of school activities.

The aim of good lighting rather than being a purely formal exercise to provide enough illumination to enable building users to go about their tasks safely and comfortably, though this must always be a prime aim, is to create a pleasant environment which enhances the building form and is in sympathy with the architectural intention.

Natural lighting during daylight hours should always be the major source, supplemented when it fades by electric light which will take over during hours of



darkness. The reasons for this need for natural light stem both from the important link with the outside which windows provide and the essential character of daylight and its changing value throughout the teaching day which electric light cannot replicate. Though desirable, it is not always possible to combine arrangements for admitting daylight with views out, although some window area for views out is essential; teaching and spatial needs sometimes call for glazed internal spaces, for example where natural light is admitted through clerestories and/or rooflights. In these cases, often called atria, it appears that if

the internal view is sufficiently long there is no necessity for an extensive external view, provided that they are not used for excessively long periods of teaching.

Window design, particularly in our northern climate, forms a crucial part of the architect's vocabulary, requiring a delicate balance between formal decisions, on proportion for example, and functional considerations. Surprisingly, though much of the internal and external character of buildings derives from fenestration design, one often finds otherwise attractive environments being marred by a

disruption of this balance. **Underglazing can make interior spaces dismal and gloomy, whilst overglazing can create excessive solar gain in summer and excessive heat loss in winter with attendant discomfort.** Lack of attention

to detailed window design can result in poor visual conditions, inefficient ventilation and an unattractive space.

The design of electric lighting is part of the whole architectural scheme, but sufficient care is not always taken to provide the necessary visual variety and stimulation, though schemes are usually adequate quantitively.

One of the attributes of electric lighting inherently absent from natural light is its flexibility to demand, a feature which can be harnessed in certain cases to enhance the brightness of vertical planes in positions adjacent to and away from window walls, a fact which can be exploited and used to good effect as a supplement to natural side lighting.

It is necessary to understand the means by which daylight is admitted to schools and to have an overview of the characteristics of electric lighting systems. The two are interdependent and in the best designs this fact is understood and acted upon.

The aim of this bulletin is to give advice and examples of how a proper synthesis can be and is achieved. The bulletin has a 'layered approach'. It takes the reader from the basic range of lighting considerations which will help in determining particular aims, to the structure of lighting design. It then goes on to consider various lighting options available and the implications resulting from them. The section on lighting design aims to provide positive guidance where appropriate, but not to stifle creativity.

Towards the end of the publication a check-list has been included. This is to help the designer to ensure that no aspect has been overlooked. It will also be helpful to school staff to derive the most benefit from the lighting provided in terms of the use of spaces and the maintenance of these systems.

The publication addresses the lighting of both primary and secondary schools but it does not differentiate between them.

All schools have a range of spaces, many of which are used for a number of different activities, either at the same time or at different times. It is important therefore for the designer to identify the particular activities that will, or are likely to take place in each of the spaces, in order to achieve appropriate lighting. A large part of the document concentrates on the 'general teaching spaces', with additional information for areas with specific requirements.

No differentiation has been made between lighting design for new and refurbished buildings, although the opportunities available to the designer will not be exactly similar, as the fundamental lighting requirements are the same in both cases.

It is hoped that this bulletin will provide designers with advice and guidance to help them develop successful schools in the future.

Section 2: Components of Lighting Design

The lighting design for a school needs to provide a lit environment which is appropriate for the particular interior and indeed exterior, achieving lighting which enables students and staff to carry out their particular activities easily and comfortably in attractive and stimulating surroundings.

In considering the design it is necessary to take into account a range of different and perhaps conflicting requirements and to do this bearing in mind the possible constraints. It is also necessary to consider the overall architectural concept and in turn the determinants which will enable it to be achieved. Whilst each element is important, and must be considered, the emphasis placed on each facet may not be equal.

Figure 1 illustrates the main areas of consideration for lighting design, together with the determining features and an indication of how they relate to each other. The following parts of this section describe the elements of the framework to help the designer to develop a strategy.

Figure 1: Framework showing main components of lighting design & determining factors.

2.1 Task/Activity Lighting

Functional lighting or task lighting is that which enables users to carry out their various tasks and activities easily and without visual discomfort and it is important that the designer assesses these requirements carefully.

For general teaching spaces a level of light is required which makes it easy to carry out quite small and difficult tasks. Reading and writing, typical school activities, require a minimum level of illuminance with a relatively high illuminance uniformity over the task area. Higher levels should be used for more detailed work and for particularly demanding visual tasks, such as using a machine in the workshop or studying fine detail in the art room. The higher levels can be provided by using an adjustable task light to supplement the general illuminance in the particular area required (Fig. 2) or by providing localised lighting to complement the general or ambient lighting. Localised lighting is permanently installed lighting equipment which

LIGHTING & ARCHITECTURAL INTEGRATION
Natural lighting design
Appearance of lighting equipment
Electrical lighting installation
Lighting controls
Integration of natural & electric lighting

LIGHTING COSTS
Capital costs of installation
Running costs of installation

LIGHTING FOR VISUAL AMENITY
Light pattern
Overall lightness
Colour appearance
Discomfort glare
Disability glare
Flicker
External & internal view

TASK/ACTIVITY LIGHTING
Task illuminance
Task illuminance uniformity
Colour rendering
Discomfort glare
Disability glare
Flicker

LIGHTING MAINTENANCE
Lamp replacement
Luminaire type
Cleaning & redecoration programme
Lamp disposal

LIGHTING & ENERGY EFFICIENCY
Natural lighting design - windows,etc
Lamp type
Luminaire type
Lighting controls
Integration of natural & electric lighting

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Figure 2: Use of supplementary local task lighting. [Photo: P. Locker]

provides the increased illuminance where and when it is required (Fig 3). If, however, it is impossible to define the area where a higher illuminance may be required, then it will be necessary to provide the increased illuminance over the whole area.

Another aspect of task lighting which needs to be considered is helping to define the three-dimensional qualities of the task, ie, its shape and surface texture. This will demand a directional quality in the lighting, ie, a flow of light, and can be provided for example by natural light from side windows or electric lighting used to enhance the brightness of a vertical surface.

Colour plays an important role in learning and light sources should have a good colour rendering performance: this will enable accurate colour judgements to be made. Because this requirement is necessary for a number of school activities, eg, art, science and craft subjects, it is recommended that a good colour rendering light source is used in all teaching spaces.

Colour and contrast are particularly important to the hearing impaired and the visually impaired (see 5.11). For example, downlights in reception or teaching areas produce harsh shadows which obstruct lip reading, and use of electrical socket outlets with backplates of contrasting colour located at a standard height is helpful to the visually impaired.

Visual comfort is also very important, and to avoid the possibility of eye strain and headaches it is necessary to limit the brightness range within the normal field of view. Discomfort can be caused for example by electric lighting equipment, views of the sky, or of bright lights being reflected in the task such as a computer screen or glossy reading material. Direct sunlight can also be a problem in this respect depending on the orientation of the window and its design, and it is important that these potentially glaring sources are avoided. Another aspect of visual comfort is concerned with flicker from discharge lamps which, in some cases, has been shown in recent research to cause discomfort. It is possible now to use luminaires that operate at very high

Figure 3: Complementary localised lighting using lines of suspended fluorescent luminaires and display spotlights either side of a central rooflight fitted with louvre blinds (see also Fig. 22). [Photo: P. Locker]

frequencies and largely overcome this problem.

It is essential to analyse the task/activity requirement before designing the lighting.

2.2 Lighting for Visual Amenity

Providing suitable lighting for the tasks and activities of a school is of course important, but it is equally important to provide lighting that enhances the appearance of the space – lighting for visual amenity. To do this, it is necessary to light the space so that it appears 'bright' and 'interesting'. Light surfaces, particularly the walls and perhaps the ceiling too, contribute to this impression. It is also desirable to achieve a degree of non-uniformity in the light pattern, as spaces which have areas of light and shade are generally liked, but it is important for this variation in brightness not to be too great, otherwise poor visibility or even visual discomfort may result.

The colour appearance of the electric light will also need to be considered because different lamp types produce different degrees of 'warmth' or 'coolness'.

Throughout a school, not only will there be a need for bright and airy spaces, modulated with light and shade, but there will also be a need for areas that are more private and secluded. An example of this is a story-telling area in a primary school. In this case the designer may like to consider providing an internal space lit only by electric lighting where the pattern of light is arranged to accent the story teller. A similar effect could be produced with a small rooflight. A corridor or an entrance area are other places where the light pattern should vary to provide small display areas for objects or pictures. The display areas would need to be the bright so that they attract attention.

Whilst direct sunlight on the task area can be a problem, an additional consideration in visual amenity is the enhancement of the environment by the appearance of sunlit areas; these could be in circulation spaces or in the exterior view.

Lighting for visual amenity is as important as task lighting and depends on the balance and composition of light and shade.

2.3 Lighting and Architectural Integration

The lighting of a building, both natural and electric, should enhance the architecture, and to achieve this, the electric lighting installation should be an integral part of the whole and not an appendage. Equipment should be selected to harmonise with the architectural concept and this applies equally to electric lighting equipment and the detailed design of windows. In addition, the

Figure 4: Tipton Infants' school, Sandwell. Combination of side window, clerestory light and linear electric lighting system. [Photo: P. Locker]

pattern of light must enhance the building form and be in sympathy with it, care being taken to ensure that projected patterns of light respond to this need. (Fig 5)
It has already been stressed that most parts of a school should appear bright and interesting, and that whilst lighting can make a major contribution to this, the reflectance and colour of the main surfaces will also have a major effect. It is suggested that the main surfaces of the interior are light in colour if the space is to appear light. If however there is a requirement for a more secluded space then darker finishes may be used. The use of strong surface colours should not be discounted but they need to be used sparingly.

One of the most important reflecting surfaces in a building is the floor and it is important to have this light in colour. Light carpets are likely to suffer early deterioration in general teaching spaces but there are other materials which have both a light finish and can be easily cleaned.

For the lighting to function well from the users' point of view, and be energy efficient, it will need to have the controlling switches designed and positioned to fit in with the use and shape of the space. By considering this aspect early in the design process the controlling circuits can be organised to allow the electric lighting to complement the natural lighting in a positive and energy effective way. They can also be organised to respond to the uses of the space, eg, providing accent lighting on separate circuits to the general lighting. All these matters are dealt with later.

Both electric and natural lighting must be an integral part of the architecture.

2.4 Lighting and Energy Efficiency

An effective and efficient use of energy is an important aspect of any lighting proposal and school buildings are no exception. This is in order to minimise the use of primary energy and hence reduce carbon dioxide emissions and also, of course, to reduce the running cost of each lighting installation.

Figure 5: Pattern of light enhancing the building form. Farnborough Grange Junior School. (Photo: Martin Charles)

When planning energy efficiency in lighting it is necessary to consider daylighting and electric lighting both individually and in conjunction with one another. An extensive use of natural lighting can provide considerable energy savings but daylight is not 'free' and the other environmental aspects of large glazed areas must be taken into account. Similarly, by the careful selection of energy efficient electric lighting equipment, installed in an energy effective way, together with controls which encourage the use of electric lighting only when it is required, an energy efficient lighting system can be achieved. It would be futile to create such an energy efficient scheme if the result was compromised in terms of performance and appearance. In these circumstances, users will often attempt to improve the lighting themselves, and perhaps, in doing so, destroy the energy efficiency planned.

An effective use of energy in lighting is an essential part of lighting design.

2.5 Lighting Maintenance

During the life of a lighting installation the amount of light it produces will diminish. This reduction is caused mainly by dirt building up on the lamps, the luminaires, or in the case of natural lighting, on the windows. There will also be a reduction caused by dirt build-up on the internal surfaces of the rooms, diminishing their reflectance. Lamp light output will also reduce with ageing.

These reductions in lighting levels will need to be minimised if energy and money are not to be wasted, and to do this it is important to pay attention at the design stage to the proper maintenance of the lighting installation and of the building itself. This aspect should be discussed in advance with the users of the building to ensure that they are aware of the proposed maintenance strategy and its implications and obtain their co-operation.

Poor maintenance is a cause of bad lighting and is also a waste of energy and money.

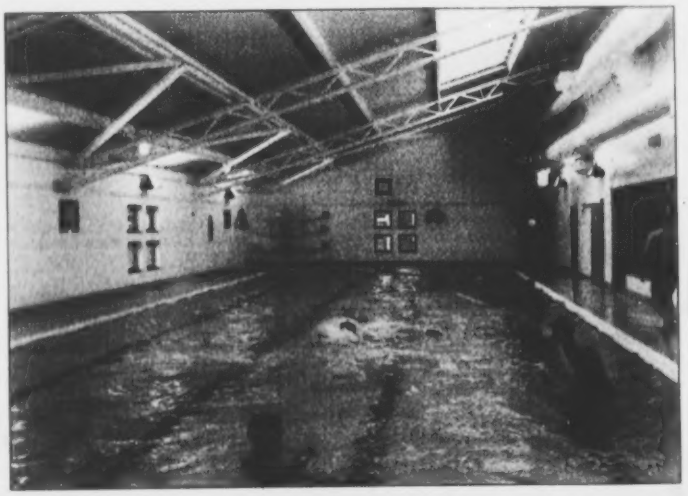
2.6 Lighting Costs

The cost of lighting can be divided into two parts; the capital cost of the equipment including its installation and the running costs which include both maintenance and the cost of energy. It is important that both aspects are considered when the lighting is being designed. In terms of capital cost, the amount will be small compared to the total cost of the building and yet lighting has a major effect on its appearance and operation, and economies need to be considered carefully to ensure that they are not false economies. Energy and maintenance costs are a continuing burden on the operation of a school and need to be taken into account at the design stage to ensure that they can be kept at an acceptable level.

For many schools, the two cost elements may be borne by different bodies which can result in a conflict of interests. It is important therefore that the lighting designer produces a scheme which takes a balanced view of energy and cost efficiency, considering both capital and running costs.

Consider both capital and running costs in concert and avoid false economies.

Swimming pool luminaires over pool surround for ease of maintenance and safety (broken glass is a hazard).



Section 3: Lighting Options

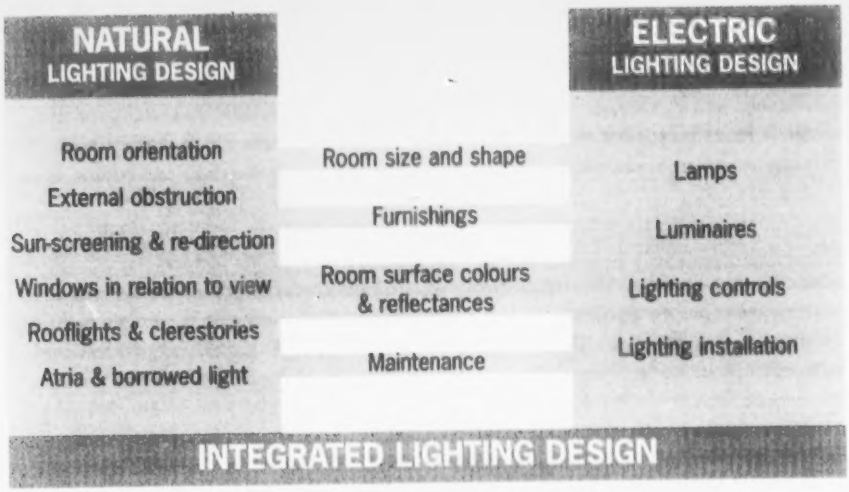


Figure 6: Options and elements to be considered in lighting design.

The diagram above shows the main lighting options - natural lighting, electric lighting or a combination of the two, together with the elements which need to be considered. These are examined in more detail in the following sections.

Figure 7: Combination of side and top light. Berrywood Primary School, Hedge End, Hampshire. [Photo: Joe Low]

3.1 Natural Lighting

Unless there are over-riding educational reasons for not doing so in certain rooms, the school designer should assume that daylight will be the prime means of lighting when it is available. This is both because of the unique quality of natural light and the link with the external environment which windows of all types provide. However, in addition to providing daylighting and a view out, windows can be a source of annoyance and sometimes discomfort, for instance when there is a particularly bright sky or when there is sun penetration which disrupts the activities within the space. Both skylight and sunlight need to be considered, and the building should be planned to take account of space organisation in relation to orientation. Windows can also have an effect on other environmental factors, particularly thermal comfort, fresh air supply, energy efficiency and noise intrusion. It can be seen therefore that windows are a complex part of building design and need careful consideration for maximum benefit and pleasure together with minimum dissatisfaction.

The means for admitting daylight can be broadly classified as follows (Fig 8):

Side windows have the advantage that they permit a view of the outside, provided that their heads and cills are at the correct level and that there are no

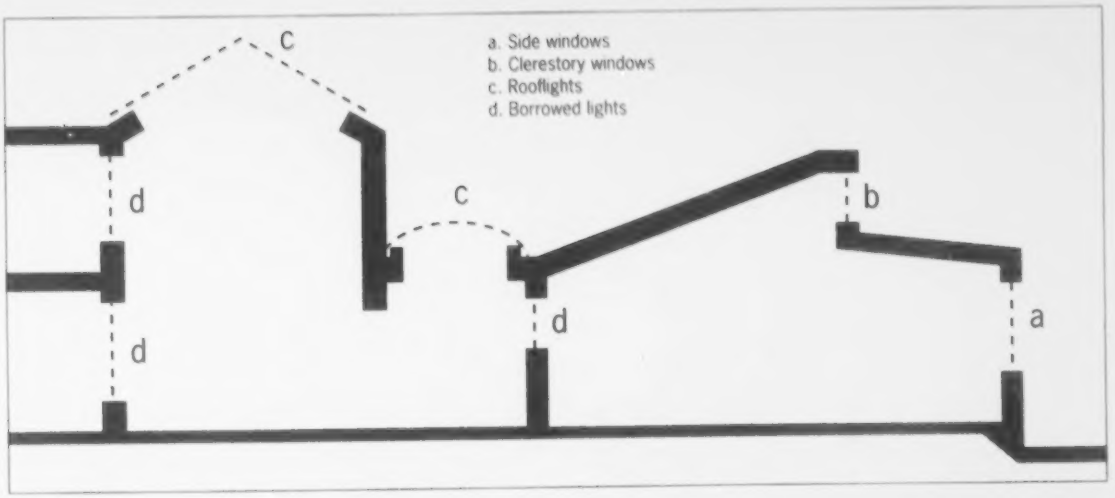


Figure 8: Window types.

intrusive transoms to obstruct this view at sitting and standing eye level positions for children and adults (Fig 9). It is more usual for trees, other buildings and rising ground to cause an obstruction in the case of side windows, though there is of course an externally reflected component of light from these obstructions.

The shape and position of windows affects the way in which daylight is distributed, wide shallow windows giving a broad distribution and tall narrow windows a deep but narrow distribution for instance (Fig 10).

Clerestory windows admit light from the brighter part of the sky and this is unlikely to be obstructed: an important feature of clerestory windows or of any high level window is that they can provide daylight deep into a space.

However, there is a higher probability of the contrast between inside and outside causing glare. They will probably not give a direct outside view but do provide information about weather conditions - cloud formation etc. Clerestory windows are usually found in single storey buildings or in those with a complex section (Fig 8).

Rooflights also admit light from the highest and brightest part of the sky, and will not generally be affected by external obstruction; they need the same care in design to take account of glare from contrast as do clerestory windows, and to give the same information about the external environment. They have the tendency to provide a more even pattern of light. It goes without saying that simple rooflights can only be employed in single storey buildings or on the top floor of multi-storey buildings. Light-wells are however a possibility in multi-storey buildings (Fig 12).

Borrowed lights. In certain cases, where rooms open off a corridor which is top lit for example, or are arranged around a top lit larger space or atrium, borrowed light can make a contribution to the light levels in areas remote from window walls (Figs 11 and 12). Although the supplement is often quite small it can help to improve the appearance of the space quite considerably.

Figure 9: Detailed window design to avoid obstruction of view.

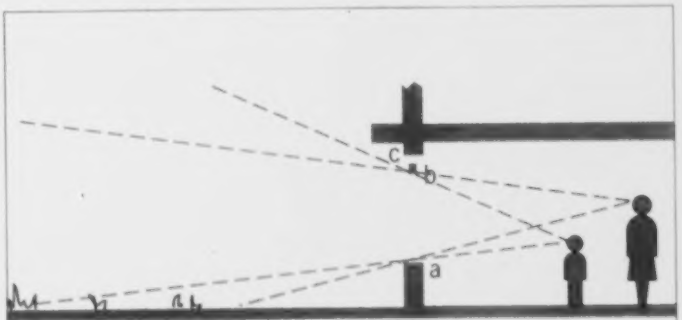


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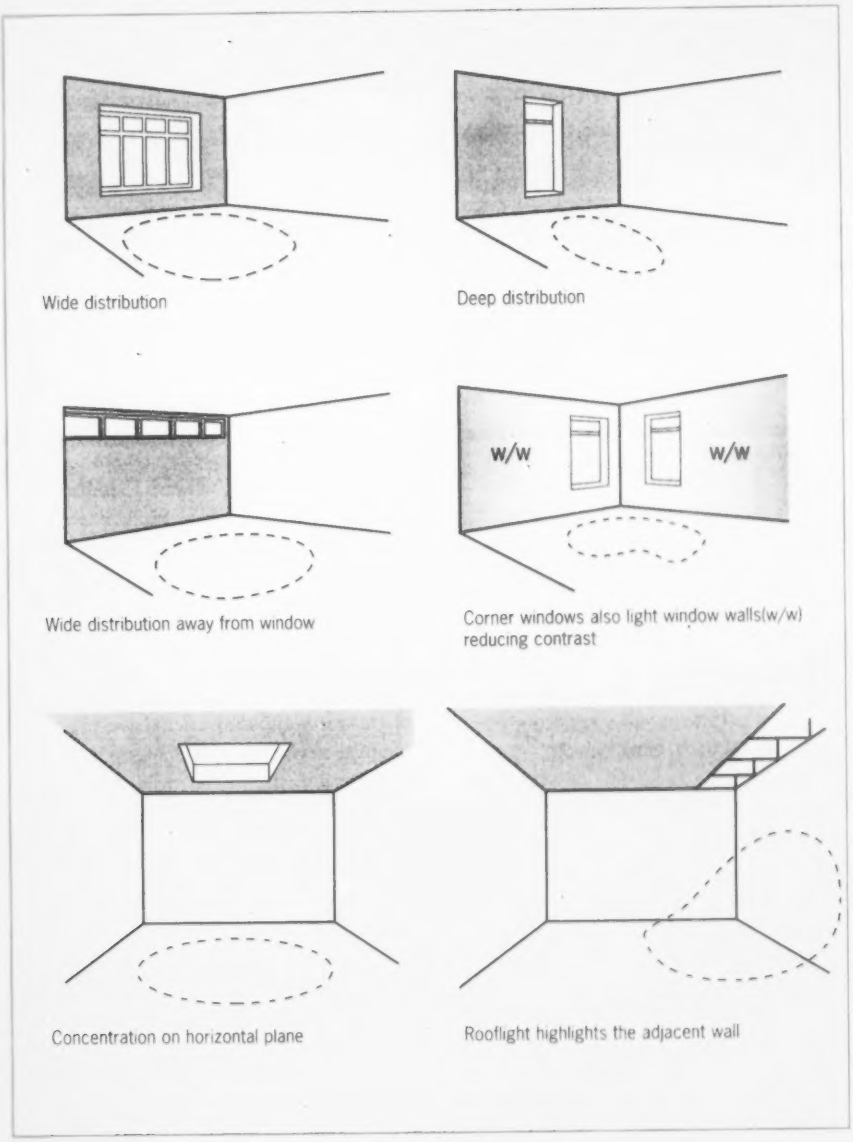
Figure 10: Indicates the relationship between window/rooflight shape and position, and light distribution.



Atria. These are large internal spaces with rooflights or clerestory windows. In schools, they are usually single or double height spaces and have the advantage of providing attractive views for the spaces around their perimeter, although the amount of light penetration to these spaces may be small, particularly at ground floor level. The atrium can be used for a variety of teaching purposes, but care will need to be taken over thermal comfort, ie, heat loss in winter and heat gain in summer. These problems can be overcome with careful consideration of sun penetration and sun control, together with the design of the roof, selection of glazing materials and the design of natural ventilation using the stack effect. The view into the atrium and the appearance of the atrium itself may be improved by planting. However, care needs to be taken to ensure that the environment is suitable for the plants selected. Care will also need to be taken to avoid visual discomfort through overglazing and some form of blinds may be necessary. Some of these considerations are discussed further in the

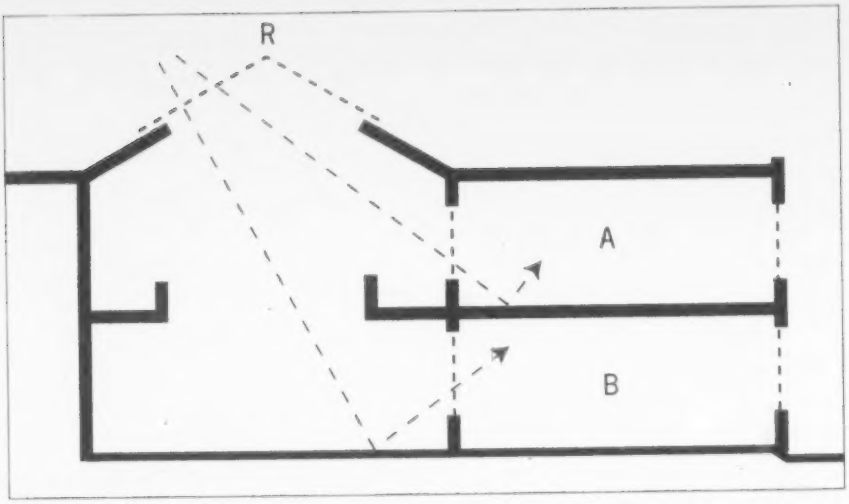


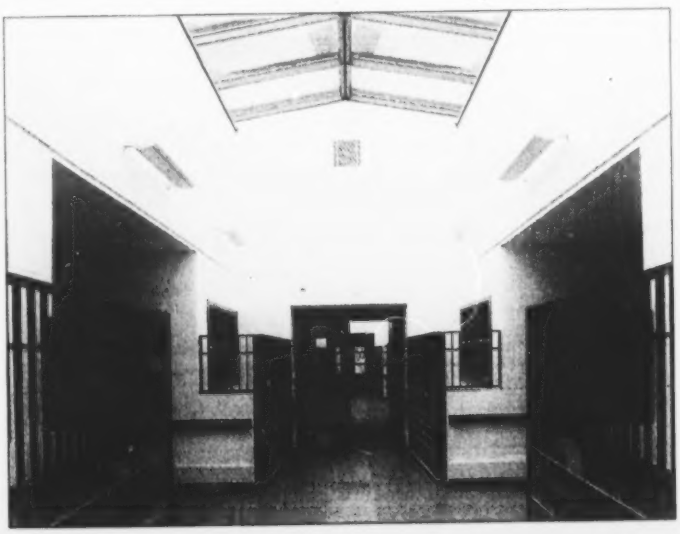
Figure 11: Diagram showing borrowed light from rooflight 'R' helping to light rooms 'A' and 'B' by direct and reflected light.

Figure 12: Borrowed light to rooms from central atrium. **Bottom left:** Fareham Tertiary College. [Photo: Joe Low] **Right:** Whitefield School, ground and first floors, with light wells to ground floor corridor. [Photo: P. Locker]

illustrative example in Appendix 8.3.

For all these window types, the sun's angle at various times of day and year should be studied as sun penetration can present a problem. However, the benefits provided by the appearance of sunlit views, particularly in non-task areas, should not be overlooked (Fig 12).

Windows provide a considerable benefit to school buildings: consider skylight, sunlight, views out and other related environmental matters



3.2 Electric Lighting

When daylight fades, on dull days and during the hours of darkness, it is necessary to turn to electric lighting. Here, as in daylighting, there are many options. The areas that need to be considered are the light sources, the luminaires, the controls and the installation itself.

The most common light source found in schools is the linear fluorescent type which can be used to provide a relatively even pattern of light. These lamps can give good colour performance, ie, colour rendering and colour appearance, good efficacy and good optical and electrical control. The more recently introduced compact fluorescent lamps (CFL) can be used either for general lighting or for task and accent lighting, and the smaller versions are a good alternative to tungsten filament lamps. These lamps also provide good colour performance and good efficacy but only a few can currently be dimmed.

The tungsten filament lamp together with the linear halogen lamp have been used extensively in the past, particularly for their low capital cost, compact size, good colour performance and ease of control. These lamps however do have a poor efficacy and a relatively short life and the designer would be well advised to consider compact fluorescent lamps as an alternative. Reflector lamps which include low voltage versions (12 volts supplied from a small transformer) and have an integral reflector are available for special display purposes. These reflector lamps have a longer life than the tungsten filament type but are much less efficient than the CFL type.

The last group of lamps considered here is the high pressure discharge type. This includes high pressure sodium, high pressure mercury fluorescent and high pressure metal halide lamps. Within this group the lamps vary in terms of colour rendering and colour appearance and this needs to be considered in making a selection for a particular situation. It is also important to note that these lamps have a time delay before reaching their full light output after being switched on and in restriking after being switched off.

The selection of luminaires will depend on the level and pattern of light required. The level of light or illuminance, will depend on the light output intensity of the luminaire and its distribution. The distribution can be first considered by reference to the simple categories shown in Table 1 below.

This is a relatively simple classification of a luminaire's light output distribution but it will help the designer to appreciate the type of light pattern that will result. It should be noted that some luminaires do not have a symmetrical light output distribution, ie, wall washing luminaires and wall mounted indirect luminaires.

The equipment selected should be

Table 1: Distribution of light from luminaires (see diagrams in Appendix 5).

Category	Upward Light	
Direct	0 - 10%	
Semi-direct	10 - 40%	
General diffusing	40 - 60%	
Direct-Indirect	40 - 60%	
Semi-indirect	60 - 90%	
Indirect	90 - 100%	

chosen to be in sympathy with the architecture. It is necessary to consider the way that luminaires are installed, ie, surface mounted on the ceiling or walls, recessed into the ceiling, or integrated into the building structure in some other way (Fig 13).

A common method of lighting schools is to use a regular array of ceiling mounted or suspended luminaires. These will provide a general wash of light which may be acceptable for lighting the task but will produce an even pattern of light which can often appear bland. If these are individually mounted or suspended, they will tend to make the ceiling appear cluttered. This can be overcome by using one of the continuous lighting systems which can combine direct, indirect and/or accent lighting (Fig 13).

Ceiling recessed luminaires are another possibility and they produce a more integrated appearance, but because they are recessed they provide no direct light on to the ceiling, and this can make the space appear underlit. However, if this type of installation is used with a high reflectance floor, then it may be perfectly acceptable.

Indirect or uplighting luminaires can be used which will generally produce

Figure 13: Top: Burnham Copse Infants' School [Photo: R Brooks, Hampshire County Council]
Left: Victoria Infants' School, Sandwell M.B.C. [Photo: P. Locker]

'light' ceilings and shadowless lighting.

It has already been stressed that some of the internal building surfaces should appear 'light', particularly walls and ceilings. To achieve this it will sometimes be necessary to light preferentially these surfaces by using wall-washing luminaires and uplighting. However this approach must not be applied to all such surfaces or the lighting will appear bland and uninteresting.

The most effective electric lighting installations are those comprising different elements which combine in terms of task and appearance, eg, general lighting, task lighting and accent lighting.

Although electric lighting depends primarily on the equipment, it is necessary to take into account the reflectance of the main surfaces of the space as well as the furnishings, and also the possible light obstruction caused by the furniture and other objects within the building.

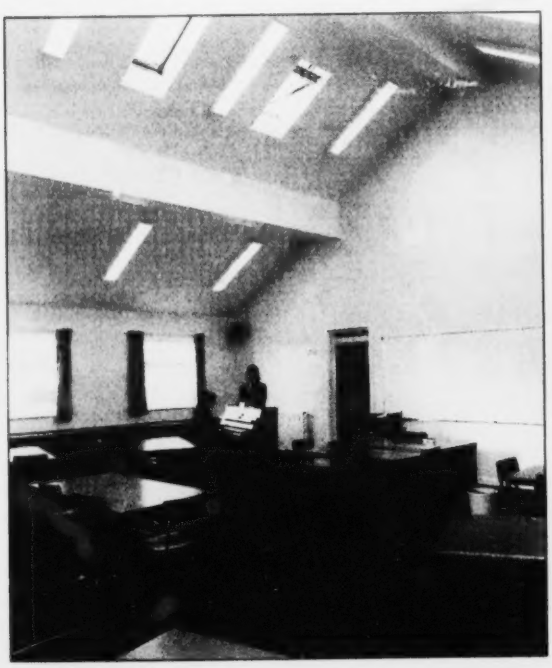
The electric lighting installation must provide for visual ability and amenity, be an effective use of energy and be in sympathy with the overall design of the building.

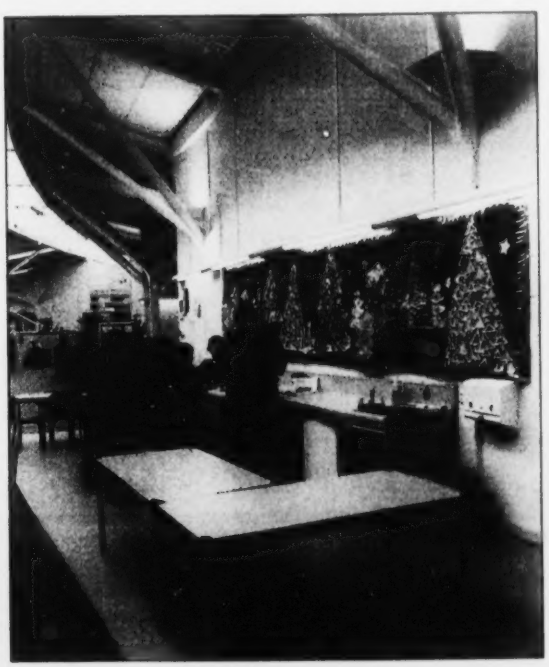
3.3 Combined or Integrated Daylighting and Electric Lighting

In school buildings most of the spaces will be predominantly daylit, with electric lighting taking over on dull days and at night. There will however be some spaces which have some daylight, but not always sufficient over the whole area. In these cases, it will be necessary to employ a system combining both daylight and electric lighting which is used as and when required. It will be necessary to consider the distribution of daylight together with the complementary electric lighting distribution to ensure they enhance one another. However, it will not be sufficient to provide a combined lighting system that only gives a uniform horizontal plane illuminance. It will also be necessary for the electric lighting installation to create the sensation of brightness in the areas remote from the windows. For this it will be necessary to highlight surfaces, particularly the walls.

For combined lighting installations consider both the task and the appearance effects.

Left: Queen Elizabeth School, Alford, Lincs.
Right: Victoria Infants' School, Sandwell M.B.C.
[Photo: P. Locker]





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Section 4: Lighting Design Guidance

4.1 Daylighting

As mentioned earlier, it is generally considered that schools should have natural lighting whenever possible. Natural lighting, however, is very variable and for design purposes, direct sunlight is excluded and an overcast sky with a defined luminance distribution is specified: in the UK, the CIE (Commission Internationale de l'Eclairage) Standard Overcast Sky distribution is used.

The design measure used is the Daylight Factor which is the percentage of the horizontal diffuse illuminance outdoors from an unobstructed sky hemisphere which is received at a point indoors: there are three components - the component received directly from the sky (Sky Component), the component received by reflection from external surfaces (Externally Reflected Component) and the component received by reflection from internal surfaces (Internally Reflected Component) (Fig 14). The Daylight Factor will vary within a space depending on a number of parameters including the size and disposition of the glazing, the dimensions of the space, the reflectance of the interior surfaces and the degree of external obstruction.

Interiors with an Average Daylight Factor of 5% or more are considered to be day-lit rooms and will not normally require electric lighting.

Interiors where the Average Daylight Factor is below 2% will require frequent use of electric lighting.

Interiors where the Average Daylight Factor is between 2% and 5% will require some electric lighting between October and March. To take full advantage of the available daylight will require an automatic daylight linked control system.

The Average Daylight Factor ($\overline{DF}$) can be estimated from the following formula:

$$\overline{DF} = \frac{T W \Theta}{A (1 - R^2)} \%$$

Where:

T = diffuse transmittance of glazing material including effects of dirt (see note)

W = net glazed area of window (m^2)

Θ = angle in degrees subtended, in the vertical plane normal to the window, by sky visible from the centre of the window (Fig 15)

A = total area of interior surfaces including windows (m^2)

R = area-weighted average reflectance of interior surfaces, including windows (see Table 3)

Note: Typical transmittance values for clean, clear single and double glazing are 0.80 and 0.65 respectively. For the value T, the glass transmittance will need to be multiplied by a factor to take account of dirt on the glass: suitable correction factors are given in table 2.

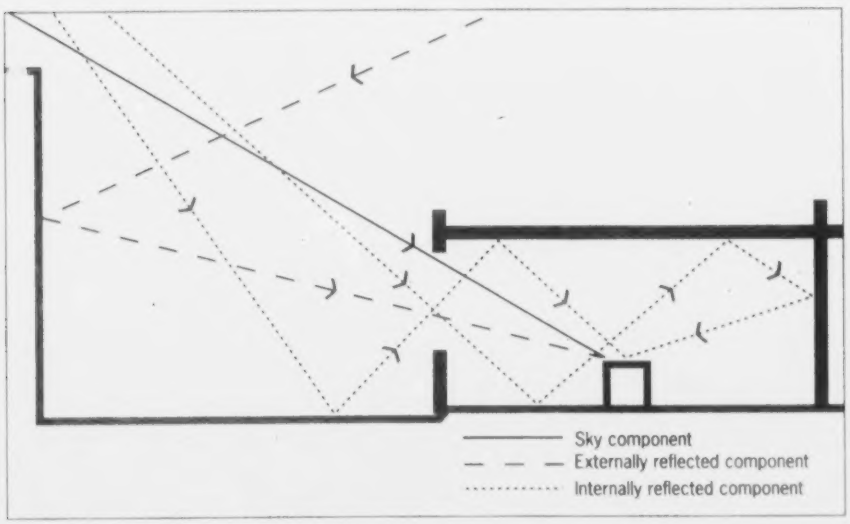

Figure 14: Daylight factor components

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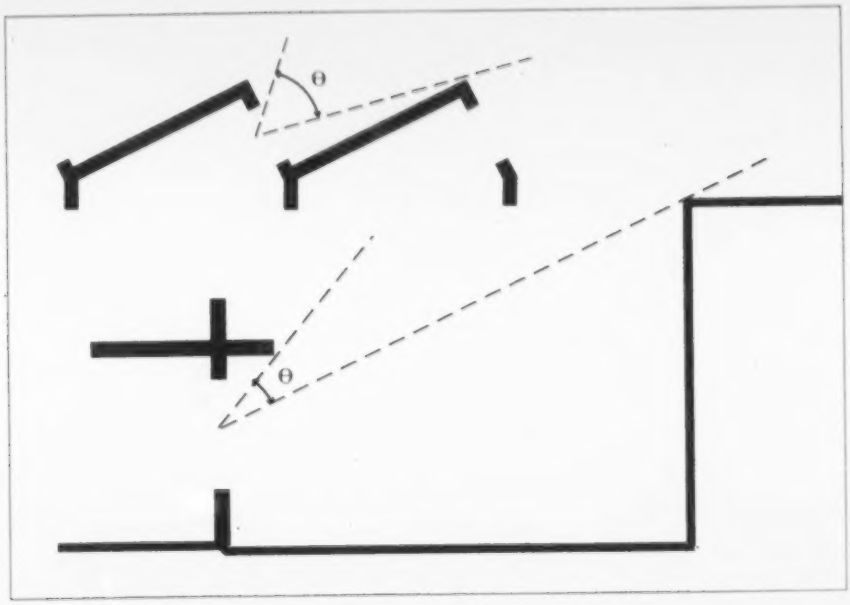

Figure 15: Angle θ which defines visible sky from centre of window/rooflight

Table 2: Correction factors to transmittance values for dirt on glass.

Correction factors for dirt on glass.

Type of location	Vertical glazing	Sloping glazing	Horizontal glazing
clean	0.9	0.8	0.7
industrial	0.7	0.6	0.5
very dirty	0.6	0.5	0.4

Reflectance values will vary depending on the surface finish: approximate values for some paints and materials are given in the following table.

Table 3: Approximate reflectance values for various surface finishes.

Paint colours	**Reflectance**
White	0.85
Pale cream	0.8
Light grey	0.7
Mid-grey	0.45
Dark grey	0.15
Dark brown	0.1
Black	0.05
Internal materials	
White paper	0.8
Carpet	0.45 - 0.1
Brickwork	0.3 - 0.2
Quarry tiles	0.1
Window glass	0.1

More paint colours and materials are given in Tables 5.8 and 5.9 of the CIBSE Code for Interior Lighting. Information for other glasses and particular surface finishes should be obtained from manufacturers.

The glazing area for a required Average Daylight Factor can be obtained from a re-arranged formula.

The above formula is applicable to vertical glazing and to some rooflights: rooflights which have an upstand or skirt require an additional term to take account of inter-reflection and absorption (see CIBSE Applications Manual: *Window Design*).

It is also useful to consider the uniformity of the daylight. The Uniformity Ratio is defined as the Minimum Daylight Factor/Average Daylight Factor. A Uniformity Ratio in the range 0.3 to 0.4 is recommended for side-lit rooms. Where spaces are top-lit, eg, atria, then higher uniformities should be expected of the order of 0.7.
The Minimum Daylight Factor value, required for the estimation of the Uniformity Ratio, can be obtained by means of one of the commercially available computer programs or using one of a number of tabular or diagram calculation methods which are described in Part B1 of CIBSE Applications Manual: *Window Design*. The position of the Minimum Daylight Factor can usually be estimated from a study of the room plan relative to the window placing.
The purpose of using the daylight

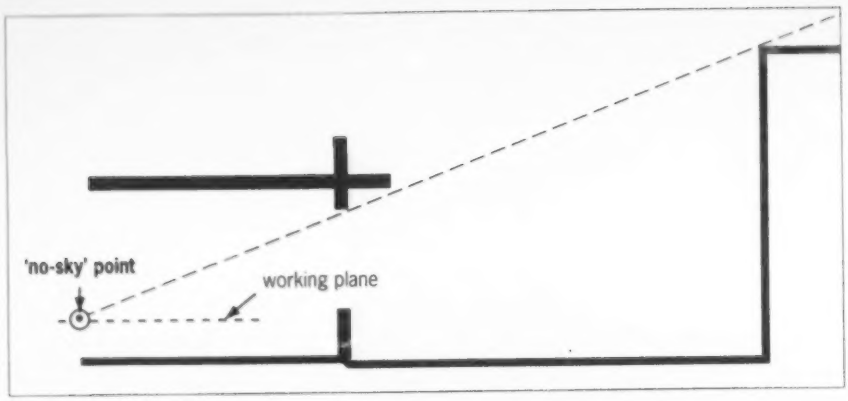

Figure 16: No-sky line: locus of points beyond which there is no direct light from the sky.

Uniformity Ratio as part of the design criteria is to ensure that a daylit room does not have any areas which will appear dark. Another way of considering this aspect of design is to take account of the 'No-sky line'. This is the line, on the floor or horizontal working plane, beyond which no direct light from the sky will reach. The area beyond this line will usually receive very low levels of natural light and this will usually require supplementary electric lighting (Fig 16).

4.1.1 Daylight Quantity

By the definition of Daylight Factor (DF), the illuminance provided by the daylight can be determined from:

$$\text{Interior Illuminance (lux)} = \text{Exterior Illuminance (lux)} \times \frac{DF}{100} \times \text{Orientation Factor}$$

The Window Orientation Factor is introduced because even with overcast skies, there is a noticeable variation in luminance, with the southern sky having the greatest effect. Values of Orientation Factor are given in the following table (for a 09.00 - 17.00 day):

Orientation of Window	Orientation Factor
North	0.97
East	1.15
South	1.55
West	1.21

For intermediate orientation, linear interpolation can be used.

Table 4: Window orientation factors for calculation of interior illuminance.

In determining the illuminance provided by daylight, the variability of the exterior illuminance must be taken into consideration, and Figures 17 and 18 provide data on the availability of daylight for a typical year for both London and Edinburgh.

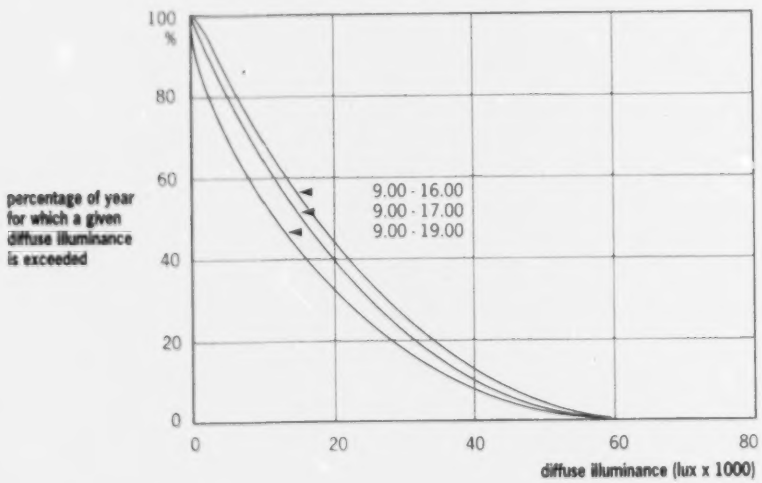

Figure 17: Daylight availability for three different lengths of day in London.

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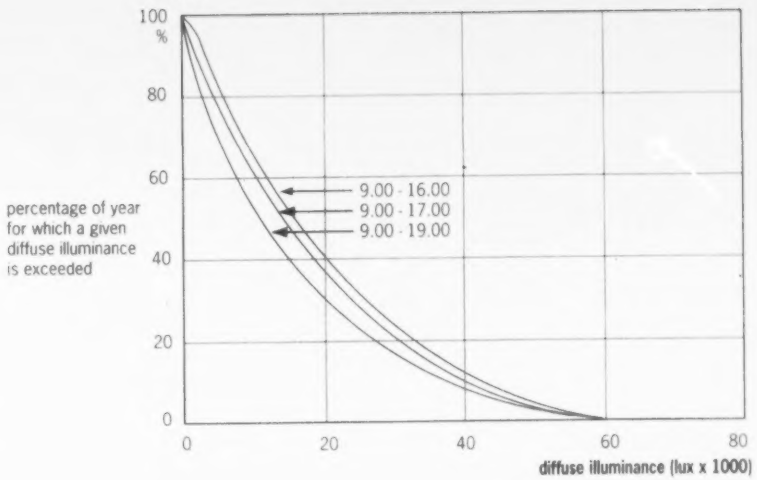

Figure 18: Daylight availability for three different lengths of day in Edinburgh.

Note: Figures 17 and 18 from BS8206: Part 2: 1992 are reproduced with the permission of BSI. Copies of complete standards can be obtained by post from BSI Publications, Linford Wood, Milton Keynes, MK14 6LE.

In order to achieve the daylight recommendations in rooms lit from one side, it can be useful in single-storey buildings and the top floor of multi-storey buildings to consider the additional use of rooflights or clerestory lights remote from the windows. This can produce an improved distribution of light in the space (Fig 19). The estimation of the combined effect of the individual parts for the average daylight factor can be made using the method described above. (For further details see CIBSE Applications Manual: *Window Design*).

However, when the daylight recommendations cannot be satisfactorily achieved, recourse must be made to the integration of electric lighting with the daylighting (see 4.3 below).

By providing good natural lighting, considerable energy savings can be made, but, as stated earlier, natural lighting is not 'free'. Large areas of glazing can result in considerable heat loss in winter and heat gain in summer, and can also cause visual discomfort. These problems can be successfully overcome if all aspects of window performance are properly

Figure 19: Queen's Inclosure Middle School, Cowplain, showing use of rooflight in centre of building. [Photo: R Brooks, Hampshire County Council]

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considered early in the design process. This may mean including double glazing or one of the new glasses which have a high effective thermal insulation (which can also reduce noise interference from the exterior). Whilst many provisions, including blinds and sunshading devices, will increase the initial building cost, they have the potential of considerably reducing running costs, and a balanced view needs to be taken.

The build-up of dirt on glazing will gradually reduce the amount of daylight entering an interior, and windows and rooflights need regular cleaning: it must be easy to reach them or maintenance is likely to be poor or expensive. Experience indicates that both surfaces of external glazing should be cleaned at least once a term, the frequency being greater in districts which have a high level of airborne dirt. (It should also be appreciated that children's work displayed on external glazing will reduce the daylight in the room). Surfaces of rooms will also need regular cleaning and redecorating to maintain the level of reflected light.

Note: In the past many schools have suffered from poor environmental conditions. It seemed that they had either an appropriate daylighting performance and an uncomfortable thermal environment or vice versa. The reason for this condition was usually a lack of an overall design solution. It is important to remember that in this country the daylighting and thermal conditions vary considerably throughout the year and the building design needs to be able to take account of these variations. For example, if a window is large enough to provide sufficient light in winter together with acceptable view conditions, then it is possible it may provide over-heating and discomfort glare in summer. To overcome this possible problem, some form of adjustable external sun-screening may be necessary as well as adequate natural ventilation. To minimise heat loss in winter the window must have appropriate thermal insulation (U-value). As mentioned earlier, this may well require double glazing or one of the new glasses which minimise heat loss through the use of special coatings. It will also be necessary to ensure that the other elements of the building, ie, the roof and walls, minimise heat loss and heat gain. It is important to stress that the environmental performance of the building needs to be considered in an holistic way to ensure an acceptable performance at all times.

4.1.2 Daylight Quality

In addition to providing the right quantity of light, daylight can give to an interior a particular unique character. Some of this is due to the variability of the daylight including sunlight: also, the distribution of the light enhances the visual field. The directional properties of light from side windows (the 'flow of light' across the room) are a significant attribute contributing to the modelling of the interior, including objects within it and surface textures, and providing brightness to vertical surfaces, the amount depending on the reflectance. Some variability across room surfaces is also important (Fig 4).

It is recommended that the reflectance of the wall surface finish should not be less than 0.6 because the effective wall reflectance will be reduced by the presence of furniture and pin-up material. With regard to the ceiling, in order to enhance the daylit appearance of a space, the reflectance of the ceiling surface finish should be as high as possible, and at least 0.7.

4.1.3 Glare

One of the most important aspects of obtaining a satisfactory interior environment is to provide a balanced luminance distribution - some contrast but not excessive. If the luminance of the sky seen through a window is very high and close to the line of sight of a visual task of much lower luminance, disability glare can occur due to a reduction in the task contrast making details impossible to see and thus reducing task performance. An example of disability glare can occur where there is a window in a wall on

which there is a chalkboard: this should be avoided.

Discomfort can be experienced when some parts of an interior have a much higher luminance than the general surroundings: it may take some time to become apparent. Discomfort glare from daylight can be a more common occurrence than disability glare, and under most circumstances its degree will depend not on the window size or shape, but on the luminance of the sky seen in the general direction of view. Data suggests that for the UK an unprotected window will be uncomfortably glaring over a significant period of the year. It has been predicted that skies with an average luminance exceeding 8900cd/m² (corresponding to a whole-sky illuminance of 28000 lux) will cause discomfort glare, and in the UK these are experienced for about 25% of the working year.

Some reduction in the sky glare can be achieved by reducing the contrast between the window and its surroundings, for example, by the use of splayed light-coloured reveals or increasing the brightness of the window wall by increasing its reflectance, or lighting it from a window in an adjacent wall. Window frames should be as light in colour as possible, whether stained or painted timber, or painted or integrally coloured metal or plastic. However, the

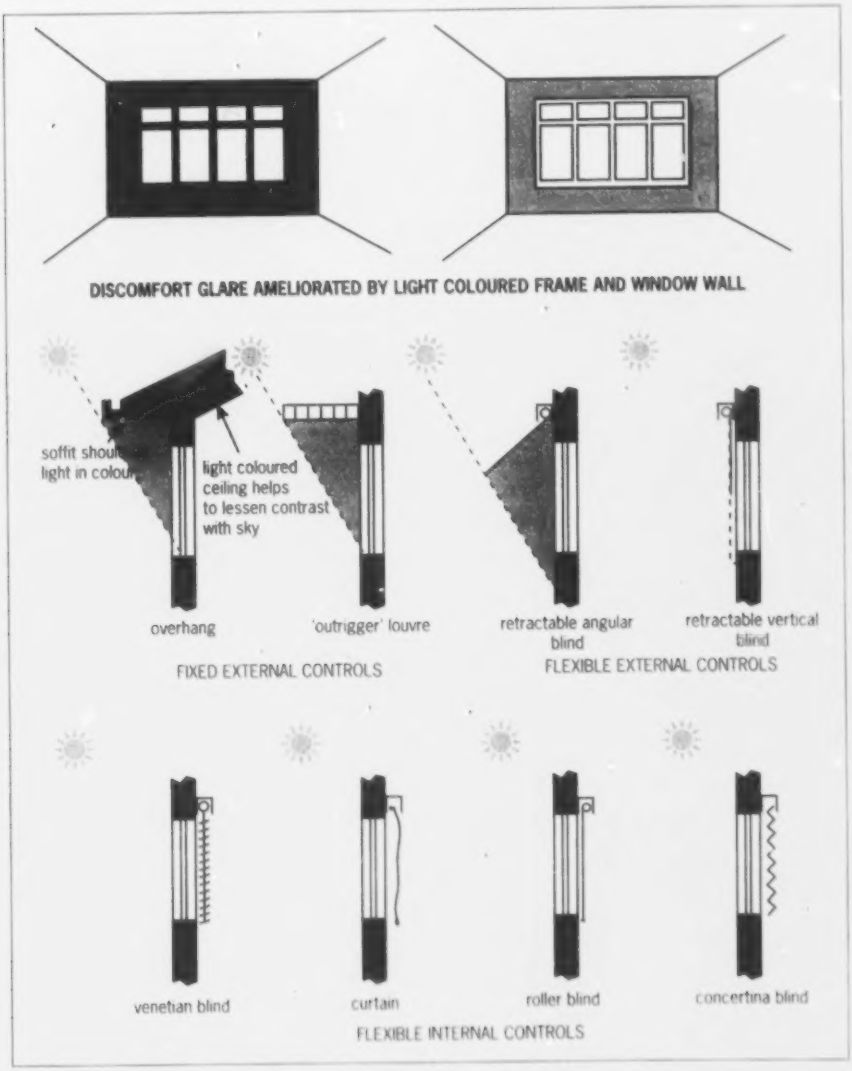

Figure 20: Examples of glare and sun control, blinds may be either opaque or translucent.

reduction of the sky luminance is the major consideration, and where this is likely to be a problem provision should be made for blinds (eg, horizontal or vertical louvre blinds) or curtains, which can be translucent or opaque and internal or external, or retractable screens, canopies or awnings. Permanent features such as roof overhangs may also assist in this matter. However, it has been shown that in the UK, overhangs of more than 300mm over windows serve little purpose in terms of shading or improved daylighting (see DfEE Building Bulletin 79, *Passive Solar Schools, A Design Guide*). If the underside of the overhang is light in colour, the penetration will be improved and excessive contrast with the sky can be avoided (Fig 20).

Rooflights can cause discomfort glare for most of the working year if the glazing can be seen directly from normal viewing positions at angles of less than 35° above the horizontal (Fig 21). The glare can be ameliorated by using measures similar to those for vertical windows (Fig 22). Contrast between the glazing and its surroundings can be reduced by using coffers with high reflectance sides which also cut off the view of the direct sky and by setting the rooflight in a light-coloured ceiling. The luminance of the sky seen can be reduced by adjustable blinds, shades or louvres. The use of a permanent diffusing panel to close in a coffer at ceiling level can provide unsatisfactory conditions: it may become difficult to appreciate that the source of light is natural and the feeling of 'daylight contact' may be lost, particularly if the exterior glazing material is also diffusing (see 4.1.5). Further, on dull days, there will be a noticeable reduction in the amount of contributed light.

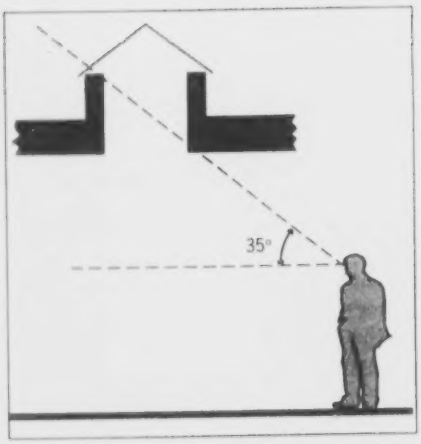

Figure 21: Rooflight glazing should not be visible below a cut-off angle of 35°.

4.1.4 Sunlight Control

While most of the time sunlight is considered to be an amenity in this country, there are occasions particularly in the summer months when it is necessary to provide some protection from its inconveniences such as excessive direct

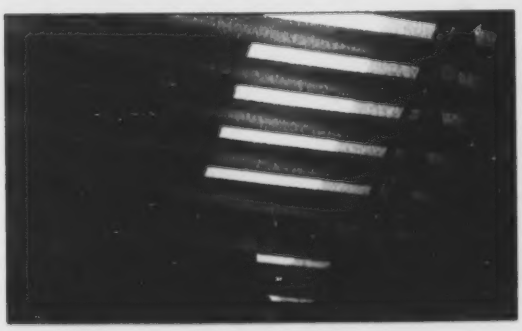

Figure 22 Left: Victoria Infants' School, Sandwell M.B.C. Motorised perforated metal louvre blinds fitted to rooflights over classrooms (see also Figure 13). [Photo: P. Locker, Photo Graphic Design]
Right: Netley Abbey School showing use of translucent roller blinds. [Photo: J. Low]

heat and glare, and shading devices are required. These can usually be designed in conjunction with the devices considered for the reduction of sky glare (see section 4.1.3).

It is not usual in the climate of this country to design permanently fixed features because they will reduce the amount of daylight entering the room at all times and this could be particularly undesirable in the winter months.

The protection can be provided by adjustable screening devices such as curtains and blinds including louvre blinds (Fig 22). For optimum sun protection, the solar control devices should be placed outside the window: retractable screens, canopies or awnings can be used here (Fig 20). It is important in designing a sunlight control system that it takes into account the extent of the use of the school during the summer months.

4.1.5 Exterior Visual Contact

In addition to providing natural light, one of the main properties of windows is the provision of visual contact with the outside. This avoids a feeling of enclosure and claustrophobia, and also provides visual relaxation and a 'view'. Wherever possible, the shape, size and disposition of the windows should be related to the view, and avoid any deprivation or curtailment of it by their position, height or width. A minimum glazed area of 20% of the internal elevation of the exterior wall is recommended. Any serious obstruction to the view can be annoying and appropriate sill and head heights are important (Fig 9).

While the view out should preferably have close, middle and distant components, and contain some natural elements, frequently this is not possible, and a popular alternative is the use of courtyards. For these to be successful, they must be well maintained, preferably with suitable landscaping and some views of the sky, and have an adequate view dimension across the courtyard of not less than 10m.

In some instances, a reasonable view of the exterior may not be feasible, and in these cases a long internal view is a useful addition - within a large space or possibly through glazed partitions. However, it is preferable to have a feeling of 'daylight contact' maybe from rooflights and including atria (Fig 19).

On some occasions, a view out can be a disadvantage and cause distraction, and in these circumstances, blinds or curtains should be provided. In addition, there are situations where there is a need for privacy and here the view into a building needs to be considered.

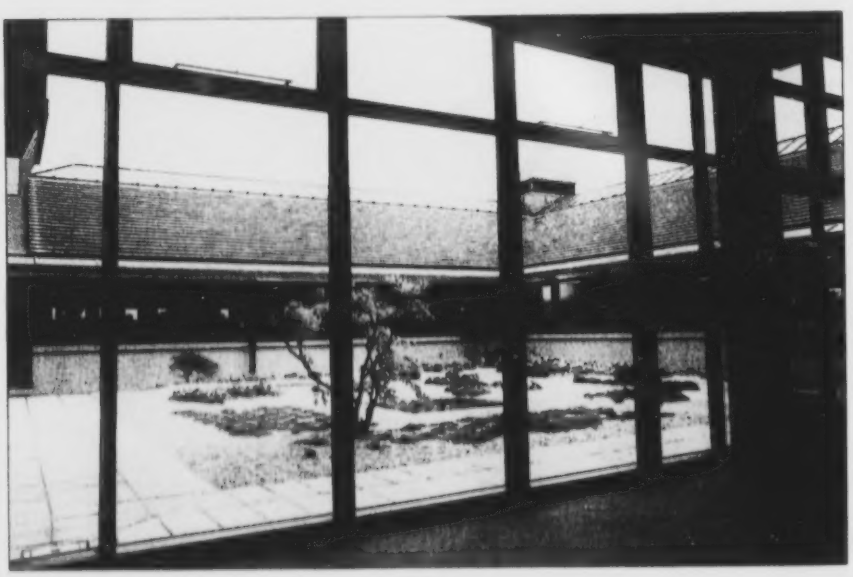

Figure 23: Courtyard view.

4.2 Electric Lighting

As with natural lighting, the main aims are concerned with:

function - to enable tasks to be performed accurately and comfortably and to facilitate safe movement about the building, and

amenity - to light the interior of the building in order to provide a pleasant and stimulating environment.

The values of illuminance quoted in this document are given in terms of 'Standard Maintained Illuminance' which is the form of recommendation used by the national and international lighting institutions. This is the minimum illuminance which should be provided at all times through the life of the installation.

The CIBSE *Code for Interior Lighting*, 1994, 'Section 2.6.4.4 Public and education buildings' provides figures for a wider range of specific interiors and activities.

An illuminance of 500 lux for demanding tasks may be provided by using local lighting to supplement general lighting: under these circumstances, the illuminance on the surround area should ideally not be less than one third of that of the working area to avoid excessive contrast and distraction.

Because of the special characteristics of atria and in particular the spatial considerations, it is advised that an illuminance of not less than 400 lux with a high uniformity should be used for these areas and in addition, light vertical surfaces incorporating high reflectance values should be a feature of the design. The lighting of atria is discussed in more detail in the illustrative example in Appendix 8.3.

Many rooms in educational buildings, and particularly spaces in primary schools, are used flexibly for a variety of purposes without very fixed work places. The lighting arrangements must reflect this requirement and provision made by controls and particularly switching facilities to satisfy this flexibility.

Lamps and luminaires need to be regularly cleaned to minimise the deterioration of their light output performance. To ensure this can happen

		Standard Maintained Illuminance lux	Uniformity Ratio	Limiting Glare Index
1.	General Teaching Spaces	300 *	0.8	19
2.	Teaching Spaces with close and detailed work (eg. art and craft rooms)	500 *	0.8	19
3.	Circulation Spaces: corridors, stairs	80 - 120	-	19
	entrance halls, lobbies & waiting areas	175 - 250	-	19
	reception areas	250 - 350	-	19
4.	Atria	400 *	-	19

Table 6: Illuminance, Uniformity Ratio and Limiting Glare Index for schools.

*Although particular illuminance values are quoted for the different areas, a small variation in these values is unlikely to be a problem.

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with the minimum of fuss, it is necessary to consider maintenance when selecting the lighting equipment: luminaires which require the use of special arrangements for cleaning and re-lamping should be avoided unless there is definite provision for this matter. The possibility of installing an incorrect lamp can be reduced by keeping the number of different lamp types used in a building to a minimum. This particularly applies to fluorescent lamps where it is possible to use the wrong colour and with spot lamps where it is necessary to ensure the correct beam characteristics are used.

In a typical school, all electric lighting equipment should be cleaned at least once a year. The cleaning should be more often in districts which are particularly dirty. As in the case of natural lighting, the level of reflected light needs to be maintained by ensuring the room surfaces are kept clean and repainted regularly.

4.2.1 Glare

Disability glare does not usually occur from electric lighting in ordinary interior spaces, but discomfort glare caused by luminaires can be a problem. This is controlled by the luminance and size of the glare source, its position in the field of view and the visual adaptation given by the background luminance. These factors when combined in the Glare Evaluation System described in CIBSE Technical Memorandum No. 10 produce a Glare Index which should be below the specified Limiting Glare Index for freedom from discomfort glare. (Many manufacturers publish tabular data for their luminaires which enables the Glare Index information to be obtained fairly quickly.)

There is a recent tendency to adopt luminaires with tightly controlled downward light distributions in the belief that this will minimise direct glare, particularly in areas where VDUs are in use. This is true for distant views of the luminaire but the student is often left with a bright light source directly overhead which can be disconcerting and can make reading text printed on a glossy surface almost impossible. A luminaire in which the lamps are not directly visible from below may be preferable to avoid high luminance reflections on the horizontal working plane.

Direct glare from a ceiling mounted luminaire depends on a number of factors including the contrast between the luminaire and the ceiling surface. With the narrow downward distribution the only light reaching the ceiling may be that reflected from the work surfaces below and the contrast with the luminous area of the luminaire may be high. A luminaire, perhaps surface mounted or suspended, depending on the ceiling height, which emits light directly on to the ceiling will reduce this contrast and be more generally acceptable. Various types of luminaires are detailed in Appendix 5.

4.2.2 Flicker and High Frequency Operation

Electric light sources, particularly some discharge lamps, can frequently be seen to flicker, a problem that can cause discomfort or even annoyance to some people. This is caused at the cathode of the lamp and by oscillation in light output which can also produce stroboscopic effects with moving objects: these can be dangerous - for example, rotating machinery in a workshop can appear to be stationary.

This phenomenon can usually be overcome by the use of luminaires with high frequency control gear. These do not remove the oscillation but raise the rate to a very high level which is not perceived by humans. An additional advantage of using high frequency control gear is the improved efficacy that can be obtained from the lamps.

4.2.3 Veiling Reflections

High luminance reflections in a task are referred to as veiling reflections, and can affect task performance due to a reduction in the task contrast and could cause discomfort or distraction: the term 'reflected glare' is sometimes used. The task detail or its background, or both, is likely to have some degree of specularity, and any high luminance source situated in the offending zone will be specularly

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reflected to the observer.

Common examples of the veiling reflection problem occur with VDU screens, glossy paper and shiny instruments, and with windows or luminaires in the offending zone (Figs 24 and 25).

Veiling reflections can be reduced by using matt materials in the task area, by reducing the luminance in the offending zone or by altering the geometry of the situation so that the high luminance is not in the offending zone.

4.2.4 Distribution of Light

The appearance of a space is controlled to a large extent by the distribution of light within it. It is important that the walls and ceiling receive light, ideally both directly from the luminaires and by inter-reflection, and to ensure this happens the selection of luminaires is important (see Appendix 5).

For a space to have an acceptable overall lightness, it will be necessary to use relatively high surface reflectances, ie, wall finish reflectance not less than 0.6 with a ceiling finish reflectance not less than 0.7 and a floor reflectance as high as is practicable. Glossy finishes to ceilings and walls should be avoided to minimise confusing reflections and glare. (Note: since it is common practice for teachers to use the wall surfaces for display, a lower average wall reflectance value, eg, 0.3 - 0.5 will need to be used for calculations,

Figure 24: Veiling reflections, schematic diagram of 'offending zone'.

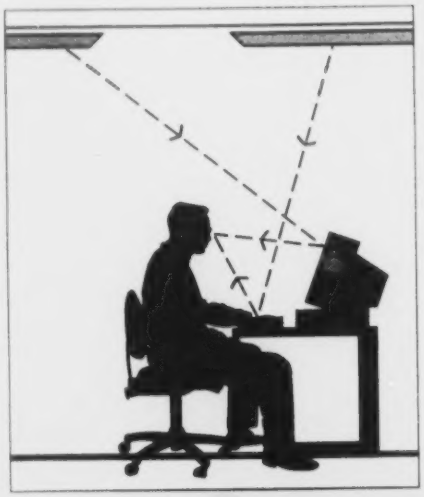


Figure 25: Veiling reflections on vertical and horizontal surfaces.

Figure 26: Preferential lighting of wall and display surfaces.

depending on the wall finish and the amount of display material.)

As with natural lighting, character and interest can be given to the interior if some directional light is introduced to provide modelling and some variety is provided by controlled visual contrasts on the main surfaces. The preferential lighting of some wall surfaces, using spotlights which produce soft-edged pools of light or wall-washing by tubular fluorescent lamps, is useful for this purpose and, of course, lighting for the display of particular items such as pupils' work can assist this process (Fig 26 and 27). It is suggested that the average supplementary illuminance on the wall surface is at least 200 lux when the horizontal reference plane illuminance is 300 lux, and this should be scaled up when the horizontal plane illuminance is 500 lux.

As stated earlier, the most effective electric lighting designs are those comprising different elements which combine to make a successful lighting installation in terms of function and appearance - for example, general lighting, task lighting and accent lighting.

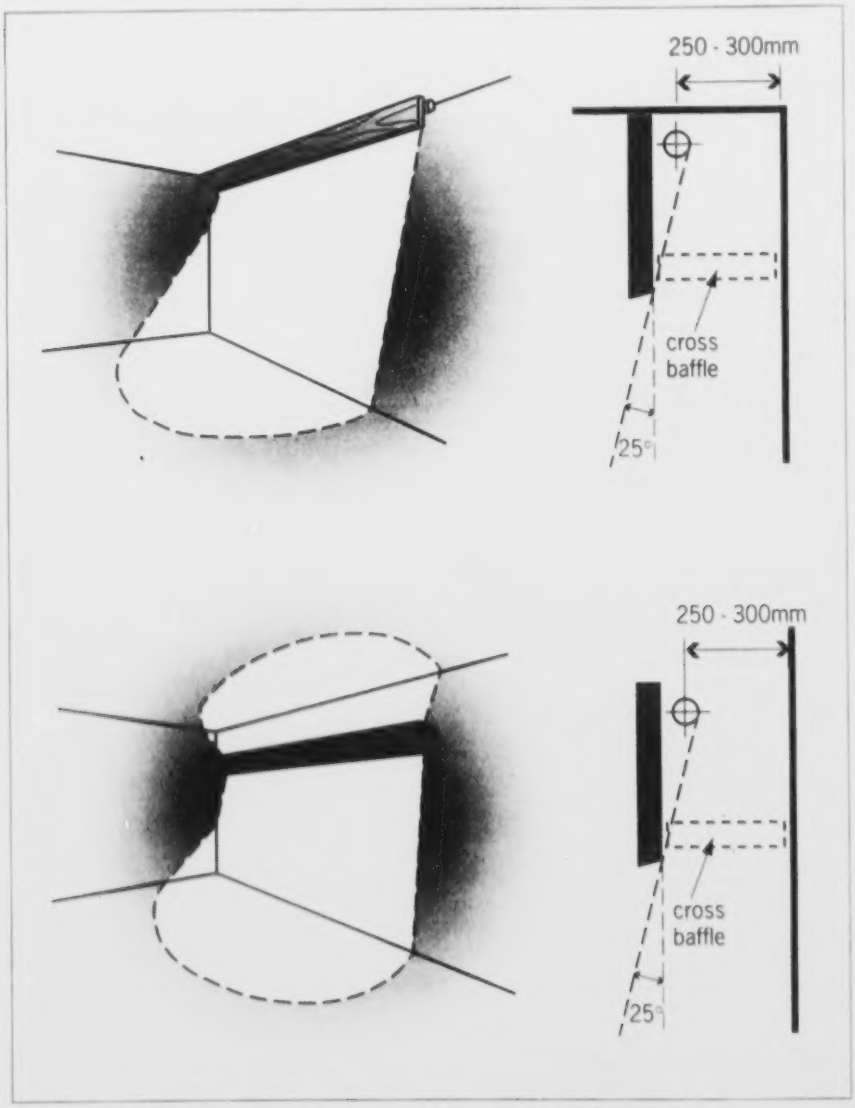


Figure 27: Examples of wall-washing luminaires which can be used for preferential lighting.

4.2.5 Choice of Lamp and Luminaire

Energy efficiency in electric lighting is a matter of selecting equipment which produces the lighting required in an energy effective way, and which is only used when it is actually needed. This will require choosing lamps which have a high efficacy, ie, those lamps which provide high levels of light for the energy they consume, and using luminaires which have high light outputs as well as controls to provide electric lighting which complements the natural lighting.

The choice of lamp will be dependent on a number of parameters, including luminous efficacy, total light output (or wattage), colour rendering, colour appearance, life, size, need for control gear, starting characteristics and, of course, cost. Some typical characteristics for the types of lamp most suitable for use in schools are given in Appendix 3, and greater detail can be obtained from the manufacturers.

While some properties including efficacy and life are of paramount importance in selecting the most efficient and economically acceptable scheme, much consideration has to be given in schools to the colour properties. Two colour properties, related to the spectral composition of the emitted light, are normally specified. One is colour appearance concerned with the apparent colour of the light and is indicated by its Correlated Colour Temperature (CCT) and the other is colour rendering concerned with the effect the light has on the colours of surfaces - this is quantified by the CIE General Colour Rendering Index (Ra). For practical purposes, CCT values and Ra values are grouped according to the descriptions given in the table in Appendix 3. For schools, it is suggested that lamps with a Warm to Intermediate colour appearance classification are used. Warmer coloured lamps with a CCT 2800K - 3000K should be used as accent lighting or in areas where a more domestic atmosphere is required. For installations where the electric lighting supplements the daylighting, it is suggested that lamps of Intermediate CCT class of about 4000K should be used, wherever possible. Due to the variations which occur in the colour appearance of daylight, the bare lamps should be screened from direct view. To enable accurate colour judgements to be made, it is suggested that lamps with an Ra of not less than 80 (Group 1B) be used.

Small light sources enable the optical control to be more accurate but, for the same output, will have a higher luminance and are potentially more glaring and therefore should be screened from normal directions of view.

It should be noted that all discharge lamps require the use of control gear for their operation and that high pressure discharge lamps have a time delay in reaching their full light output after being switched on and in re-striking after being switched off. The use of high frequency control gear with fluorescent tubes will need consideration in situations where the avoidance of flicker is important.

The choice of lamp and luminaire are, of course, interdependent and one cannot be considered without reference to the other.

The main items to be examined in the choice of luminaire are:

(i) luminous efficiency and light distribution.

These are characterised by the Light Output Ratio values (total, downward and upward) and the shape of the luminous intensity distribution (polar curve). These factors describe not only the amount of light falling on the working plane but also that on the ceiling and walls - a prime component in determining the visual appearance of the space. This light distribution data will also provide information regarding the possibility of glare being a problem. The nominal spacing/mounting height ratio will also have to be noted to achieve the recommended uniformity of illuminance. (Detailed photometric information can be obtained from the luminaire manufacturers: some typical characteristics are given for guidance in Appendix 5).

(ii) appearance.

The appearance of the luminaires,

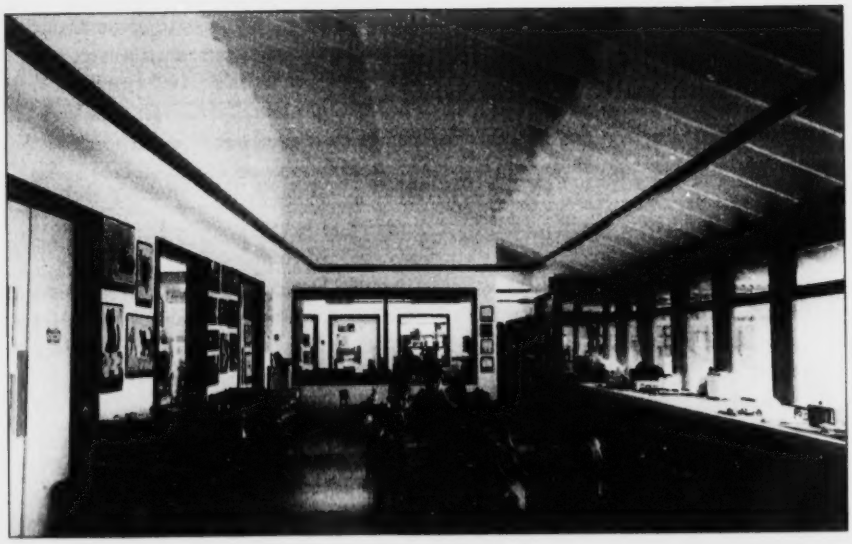


Figure 28: New Bradwell Priory Common First School. Milton Keynes. Suspended linear lighting system. [Photo: Bucks County Council].

when lit and unlit, should complement the general design of the interior. The contribution which the luminaires will make to the character of the space will have to be examined. Mounting position (ceiling recessed, surface mounted, suspended etc.) is very important in this respect (Fig 28).

(iii) ease of maintenance.

The luminaire design should, wherever possible, avoid surfaces on which dust and dirt can be deposited. It should also allow maintenance - cleaning and re-lamping – to be performed easily without the need for a special procedure.

Note: All lighting equipment should generally comply with the relevant British Standards and Euronorms or equivalent.

Note: BS 4533 : Luminaires.
Part 101 : 1990. Specification for general requirements and tests.
Part 102 : 1990. Particular requirements.

4.3 Integrated daylight and electric light

When the daylight recommendations cannot be achieved throughout the space, a supplement of electric lighting can be provided, but it is usual to require the space to appear predominantly daylit.

The first requirement is for the electric lighting to supplement the daylight so that the combined illuminance is suitable for the task or activities being undertaken, and an effective use of controls is necessary.

The other requirement is to achieve a satisfactory appearance by the balance of brightness throughout the space so that surfaces in parts remote from the windows do not seem dim and gloomy. This can occur even when there is technically enough light due to the visual adaptation caused by a relatively bright window. An appearance which is more visually acceptable can be achieved by lighting preferentially the wall remote from the windows by 'building lighting' which is separate to that required for the task. This wall lighting can be more effective when some variety is incorporated, as previously described (4.2.4). The ceiling will also need to be well-lit.

The electrical distribution circuits and their switching arrangements should be suitably organised. In many circumstances, the supplementary electric light will have to be designed to operate separately from the night-time electric lighting (see Appendix 6).

As mentioned earlier, it is advised that the lamps used for electric lighting in this type of combined lighting should be of Intermediate CCT class of about 4000K. The bare lamps should, wherever possible, be screened from direct view because of the variation which can occur in the colour appearance of daylight.

With regard to the possibility of discomfort glare for combined installations and to ensure the degree of glare from

the two installations operating together is acceptable, it is advised that each installation should be designed to be independently within acceptable limits.

4.4 Aids to Lighting Design

In this section, guidance is given on daylighting, electric lighting and a combination of the two. This includes numerical recommendations and techniques. Whilst numerical values have their place, particularly regarding visual performance and comfort, it is virtually impossible to quantify the lit appearance in the same way. As an aid to developing this aspect of design, it is helpful for the designer to use a number of techniques to enable design possibilities to be explored and ultimately tested. These include shaded perspectives and architectural models, particularly for daylight and sunlight studies, and it is likely that computer visualisation programs will become more common in the near future.

With regard to shaded perspectives, these can be used to develop the required light pattern to identify the areas that need to be 'high lit' or to explore, in a three-dimensional way, the lighting performance of a window/rooflight system. They are also particularly useful as a way of communicating design ideas.

Architectural models are commonly used to explore daylighting designs. For this purpose it is advised that a scale of not less than 1:20 be used and that they are made from materials that are opaque and have the appropriate surface reflectance and colour. It is obviously important that the models are dimensionally correct and that any external obstructions are included. It is not essential to model precisely window details such as glazing bars or glazing materials, but these must be taken into account if the model is used for measurements. It is important to include any permanent shading devices including roof overhangs. The model can be used in three ways, to appraise the appearance of the lit space, to measure the daylight distribution and to examine the direct sunlight penetration.

For the appearance appraisal it will be necessary to provide viewing slots. These need to be placed at a normal head position and can be used under real or artificial sky conditions. It is of course important that no stray light enters the model through the viewing slot. It is often easier and more convenient to use a modelscope either directly or with a camera.

When the model is to be used for measuring the daylight distribution, usually under an overcast sky condition, it will be necessary to provide entry positions for small photocells, but it must be possible to seal these openings when the measurements are being made to avoid errors due to light leakage. It is useful to measure not only the inside values but also an outside, unobstructed, sky value: which will enable the measurements to be quoted in terms of daylight factor. The measurements can be made under a real overcast sky, but it is

Figure 29: Use of model in artificial sky at the Building Research Establishment, Garston.

more convenient to use an artificial sky to overcome the problem of light level variability (Fig 29). The artificial sky is a piece of equipment which typically models the CIE overcast sky condition using mirrors and electric lamps and therefore remains constant whilst the measurements are made.

Models can also be used to test sun penetration. In this case the model can be used in conjunction with a spot lamp to represent the sun and a sundial to enable the correct relationship between the model and the spot light (artificial sun) to be established. With this equipment a range of sun positions can be explored. An alternative is to use the model in conjunction with a heliodon, a piece of equipment that enables the sun/site/building relationship to be explored more easily (Fig 30).

Whilst few design practices have their own artificial sky or heliodon, these pieces of equipment are commonly available in Schools of Architecture, University Building Departments and Research Establishments.

Calculations for the determination of point daylight factor, illuminance and luminance, have not been included in this publication because they appear elsewhere and in particular the CIBSE Publications: *Code for Interior Lighting* 1994 and Applications Manual: *Window Design* 1987.

Figure 30: Use of model in conjunction with a heliodon.

Section 5: Lighting for particular applications

The discussion in the earlier parts of this document applies to all areas of a school. However, particular spaces may need additional attention due to their specialised requirements, some of which are more commonly found in secondary schools.

5.1 Circulation Areas.

The circulation routes through a school are its main arteries taking pupils, staff and visitors from the main gate through to the various particular areas. They need to be functional in that people need to find their way easily and safely through the building, even when they are unfamiliar with it. These routes also need to be visually stimulating. Finally they need to provide means of escape and this may require emergency lighting (see Section 5.14).

5.1.1 Exterior circulation and the main entrance

During the daytime the route from the main gate to the main entrance will usually be obvious. This is because of the site organisation and the architectural treatment of the main entrance. At night-time, however, things will be different. The main gate may need to be identified, perhaps with an illuminated sign, together with a high-lit area around the gate. This area then needs to be linked visually to the main entrance of the school, which will mean lighting the walkway and vehicle routes. The important thing is to light the pavement and road surfaces; it can be done from a low height using bollard type fittings or higher post-top lanterns, but the luminance in the normal directions of view should be kept to a minimum. This is to avoid glare and to maximise the visual effectiveness of the lighting.

To aid progress across the site, the main entrance needs to be bright and welcoming. This can be achieved, if the front of the main entrance is glazed, by high-lighting the vertical surfaces within the entrance area. These can also be used for student displays and the display of school trophies. The interior light in the entrance area will also spill out into the area in front of the doorway making it inviting and helping to identify any steps. During daytime the entrance area should receive a good level of daylight particularly on vertical surfaces; however, if this is not possible then supplementary electric lighting may be necessary in display areas.

5.1.2 Corridors and stairs

The corridors and stairs are the main elements of circulation and although their prime purpose is to get people from one place to another, they are also an

Figure 31: Blenheim High School, Epsom, Surrey, main entrance. (Photo: P. Locker)

important facility in identifying the work and character of the school. They should be lit to provide safe movement around the building and also to produce interesting and, if possible, stimulating spaces. The lighting, both natural and electric, should aim to provide visual variety and an enhancement of some areas rather than others. Different surface materials and particularly different textures, can be useful in this respect. Again, the brightness of individual luminaires should be limited and they can preferentially light walls and alcoves used for sitting and display. In this instance, for single storey buildings, rooflights can make a major contribution. View windows which look out, or into some internal spaces, can be valuable sources of orientation. The electric lighting can be wall or ceiling mounted but it needs to be an integrated part of the building.

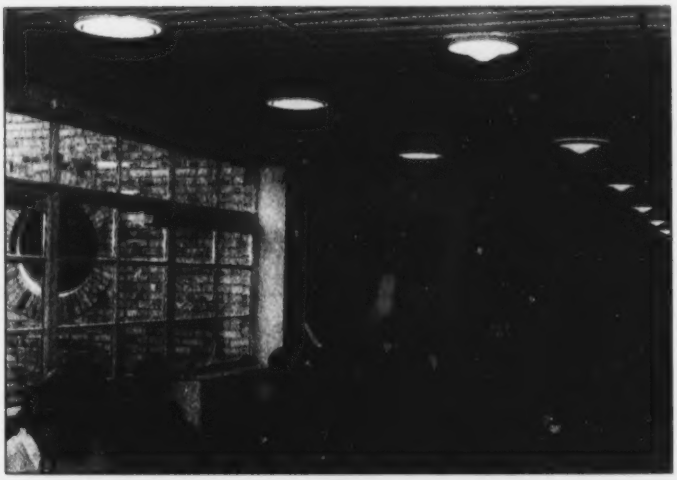


Figure 32: Low energy corridor lighting with change of luminaire and daylighting in sitting area. Netherhall School, Cambridgeshire. [Photo: P. Locker]

Stairs need to be well lit to avoid accidents. The main consideration is to provide lighting which ensures that the staircase treads and risers are well defined with a contrast between the treads and the risers and that the luminance pattern is such that there are no problems from glare. This means avoiding bright luminaires or windows in the normal field of view when using the staircase.

It is recommended that an average illuminance of 80 - 120 lux be provided at floor level in corridors and stairs. Entrance halls, lobbies and waiting rooms require a higher illuminance of 175 - 250 lux. Reception areas should be lit to 250 - 350 lux (Fig 33). Downlighters are not recommended over reception desks as the lack of a diffuse component of light makes lip-reading difficult (see 2.1)

Special attention must be given to the avoidance of glare and other visual problems. For example, the positioning of

Daylighting of staircase with contrasting treads and risers and avoidance of glare from windows. [Photo: P. Locker]

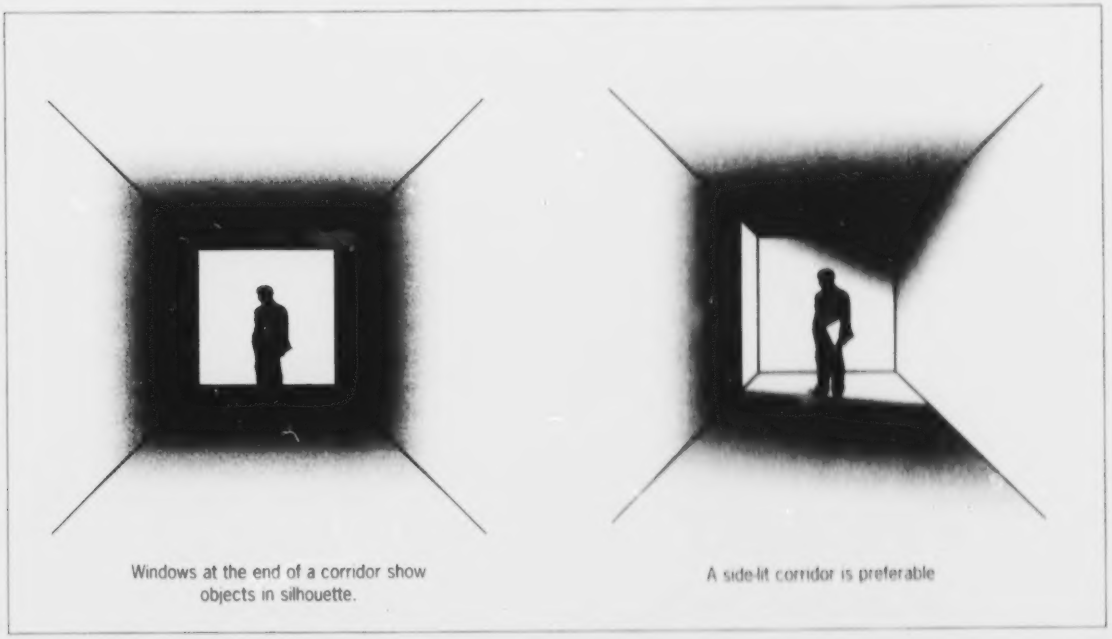
Figure 33: Main foyer and reception area at Bienheim High School, Epsom, Surrey. [Photo: P. Locker]

a window at the end of a corridor can be annoying because of the silhouette vision it can cause and can be dangerous in producing disability glare (Fig 34).

Interest and variety can be supplied in circulation areas by display and exhibition spaces, possibly in alcoves, which are preferentially lit (Fig 35). If private study areas are provided off circulation routes, they should have suitable local electric lighting, and ideally be near a window.

In primary schools, it is common for circulation to be part of general teaching spaces and vice versa. This will require the designer to decide on the particular lighting needs of this type of space. Usually the more demanding task will take priority.

Figure 34: The benefit of a side-lit corridor.



5.1.3 Circulation/activity areas

Where areas cater for other activities as well as circulation, lighting will need to consider both functions. It will be helpful if the circulation route, though part of an activity area, can be separately identified. This may be achieved with changes in the lighting, but also changes in surface colour can be used. Another possibility is a change in ceiling height which can be combined with a change in lighting. Some recent designs have daylit 'streets' which are used for a wide range of activities and also form an important focus for the school. As with corridors, these areas often incorporate displays, which may be two or three dimensional, on vertical surfaces or free-standing. These benefit from accent lighting and their changing nature requires a degree of flexibility in the display lighting. This can be achieved with a track lighting system equipped with very low glare, adjustable luminaires.

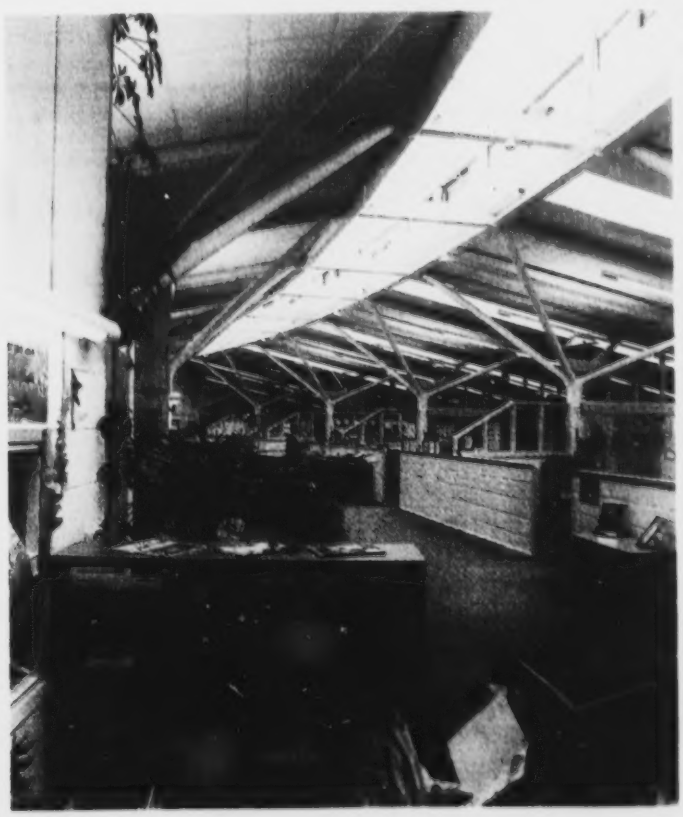


Figure 35: Circulation street with activity areas. Victoria Infants' School, Sandwell M.B.C. (Photo: P. Locker)

5.2 Areas with Display Screen Equipment

Display Screen Equipment(DSE) is the name now given to Visual Display Units (VDUs) which have become increasingly important items of teaching equipment in both primary and secondary schools. The visual conditions and correct lighting for their satisfactory use need care and attention. DSE is generally found in use throughout schools with small numbers of computers in all subject areas. Larger numbers of machines may be grouped in areas such as library resource areas and specialist computer studies rooms.

One of the main problems encountered concerns the unwanted reflections which can occur in the screens of DSE. These can be bright enough to make it difficult to read the screen characters, reducing the contrast between them and the screen background. To control this situation, the lighting of the space in front of the screen must be such that the luminance of any surface is low enough not to interfere with the reading of the screen characters; changes in luminance must be gradual, and luminaires and windows having a high luminance in directions affecting the screen must be avoided (Fig 25).

One obvious demonstration of this effect is the student's white shirt or blouse acting as a large luminous source, producing a reflection in the screen. Whether this is critical or not will depend on the luminance of the screen. Positive polarity screens (eg, *Windows* based programmes or screens with a white or light coloured background) will have relatively high brightness (70-100cd/m^2) which will significantly reduce the effect of reflected images. Negative polarity screens (DOS based programmes or screens with a black or dark coloured background) will have relatively low brightness (2-8cd/m^2) and reflections on the screen will be relatively brighter which can make it difficult to see the data displayed. With positive polarity screens there should be no problem but with negative polarity screens some action may be necessary. The students could be encouraged to wear darker clothing such as pullovers or jackets where the problem

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is greatest. Filters might prove useful in reducing the brightness and sharpness of the images and many screens are now being produced with a matt surface which will reduce the sharpness of any reflected images. Fortunately the majority of software used in schools is of the *Windows* type which produces a positive polarity display on the screens. Allowance can be made for screen brightness when choosing luminaires (see CIBSE LG3 reference at end of section) but most teaching spaces will only require to be designed for the use of high brightness screens. The 1996 edition of LG3 quantifies the changes to the luminance limiting value of a luminaire with respect to the type of software and the type of screen being used. In areas where DSE is used intensively, ie, computer rooms and library resource areas, electric lighting schemes which have been found suitable employ ceiling mounted luminaires which have a louvre type optical control system with low luminance above defined critical angles. Another possibility is indirect lighting or uplighting; this technique has the benefit of not normally creating high luminance within the offending zone. In appearance terms, a combination of both systems is preferable.

The combination of direct and indirect lighting offers a number of advantages over either direct or indirect only. Where suspended luminaires can be used (due to floor to ceiling heights greater than 3.0m) the uplighting element will increase the background surface brightness, reducing the contrast between it and the direct lighting element. By reducing the contrast it is possible to consider a less onerous luminaire distribution. For example a Category 3 louvre, as described in CIBSE publication LG3, might be replaced with a non-Category louvre. Surface mounted luminaires can also provide some light onto the ceiling but recessed type luminaires generally do not.

These techniques have been widely used in commercial premises where the spaces and rooms can be large.

In schools where classrooms are generally small in comparison with open plan offices it is much more important to consider the geometry of spaces containing computers. Relatively small rooms or those with high ceilings (more than 3.5m) may not need any special treatment other than good classroom lighting, as the luminaire mounting height may not cause any images in the screen. Simple changes in layout of equipment might also be sufficient to reduce bright images.

In most teaching spaces the number of computers in use is small and the main design consideration should be work on the horizontal plane. This includes reading, writing and practical activities. Louvre type fittings designed to reduce glare on vertical screens may still produce high luminance reflections on the horizontal plane which can make working on reflective materials very difficult. This can be a problem when reading glossy books, working on metal objects etc (Figures 24 and 25). Reflections are a particular problem for the visually impaired.

There is a tendency to specify louvre type fittings in all spaces because DSE is used to support teaching in any subject area. This is not necessary considering the small number of computers in most spaces and the simplicity of moving the screens to avoid glare from luminaires, the short periods for which computers are in use and the high brightness of *Windows* based programmes which are now in use almost everywhere.

There is no substitute for good classroom lighting design.

One element that should always be considered is the distribution of light to ensure that the vertical surfaces within the room are adequately lit. This may involve using two or three lighting installations in the same space in order that a satisfactory balance of light is achieved.

Some control over the illuminance, in rooms specially used for computing, may be considered desirable, so that the excessive initial illuminances do not cause problems to the user. Dimmable high frequency fluorescent luminaires may be considered necessary in these circumstances. These are more expensive than normal luminaires but will provide

better conditions, especially where the users are in the classroom for a long time (eg, double periods, or longer).

Windows are usually the biggest lighting problems encountered in areas containing DSE because of their relatively large size and high brightness. However, room layout can usually avoid placing computers where windows are visible to computer users as high luminance glare sources. Windows can also be screened using one of the devices discussed earlier for the control of sun and sky glare.

A wide range of luminances in the general field of view when using DSE can cause visual adaptation problems. The consequences can be a reduction in task performance and visual distraction, discomfort or even disability. The contributing luminances are concerned with the display screen, the keyboard, objects such as documents on the desk, and with the background, particularly the immediate background to the screen. An unfortunate common example of the last item occurs when a display screen is seen against a window. Measures to restrict this luminance range must be taken by controlling the distribution of the light and the position and reflecting properties of the components.

DSE is often used by an individual for a relatively short time (for example, to find one item of information), and the problems mentioned are tolerated. However, for more extended work, the visual conditions become important for satisfactory, comfortable use. Detailed guidance is given in CIBSE Lighting Guide LG3 1996: *The visual environment for display screen use*.

5.3 Science Work and Laboratories

For primary schools this type of activity will usually take place in general teaching areas, and the recommendations for those areas will usually suffice but the designer should check that there are no unusual requirements. For the secondary school laboratory where intricate tasks are undertaken which need accurate readings and subtle observations, higher illuminance may be appropriate. This can be provided by general lighting (Fig 36) or by local task lighting supplementing the general lighting.

Where fixed benching is used, adjustable bench lights are suitable, particularly where directional lighting is

Figure 36: Science laboratory, Dr Challenor's Boys Grammar School, Amersham. [Photo: Bucks County Council]

appropriate, but they must be controlled so that they do not cause distraction or glare to neighbouring work positions or become a physical encumbrance.

Visual conditions can be made more comfortable if the bench tops are made of a material which is light rather than dark in colour and has a reasonably matt surface to avoid awkward specular reflections. Advice regarding the finishes of tables etc, can be obtained from British Standard, BS 5873: Part 1 1980, *Educational Furniture*.

Demonstration benches may benefit from some preferential and directional lighting.

Many of the considerations for laboratories also apply to preparation rooms associated with the laboratories.

Good lighting is particularly important for the users of laboratory areas to avoid accidents and to ensure the safe handling of equipment.

5.4 Design and Technology Rooms and Workshops

As with other situations where detailed work is done, the lighting of areas for design and technology can most conveniently be achieved by supplementing the general lighting with local individual lighting which can be adjusted to suit the particular task, especially where directionality of the light is important but provision must be made to avoid interference to the work positions and machines and those nearby. For lathes and other machine tools, local lights are often provided on the machines. For safety reasons, these must be on an extra low voltage supply. All luminaires should be robust and it may be necessary to protect the lamps with wire mesh guards. They should be easily maintained and cleaned at least once a term because such spaces are often environmentally dirty.

A particular hazard, mentioned earlier, can occur with discharge lamps lighting machinery with rotating parts as it may be difficult to assess the speed of rotation due to the stroboscopic effect. This can be avoided by wiring alternate luminaires on different phases of the electrical supply (not usually recommended as it increases hazards during electrical maintenance), or by using high frequency control gear.

In Design and Technology areas it is often desirable to have a display space for completed work, and this should be preferentially lit. As with laboratory spaces, some preferential lighting may be required for demonstration areas.

It is particularly important for people in these areas to have good lighting to avoid accidents and to enable tools and equipment to be used safely. Good rendering of colours is very important and lamps of CIE colour rendering group 1B should be used.

5.5 Libraries

The lighting of library spaces must be co-ordinated to fulfil a number of functions - general ambient lighting, lighting for vertical bookstacks, lighting for study and lighting for browsing. It is important that the lighting arrangements are designed so that there is no conflict between the appearance of the different parts of the installation or with the light distribution throughout the space (Fig 37). Particular attention needs to be given to the avoidance of problems with veiling reflections, with glare and with the use of VDUs (see previous sections).

Ambient lighting from overhead luminaires can be used for general reading

Reference:

BS 5873 :
Educational Furniture.
Part 1 : 1980. Specification for functional dimensions, identification and finish of chairs and tables for educational institutions.

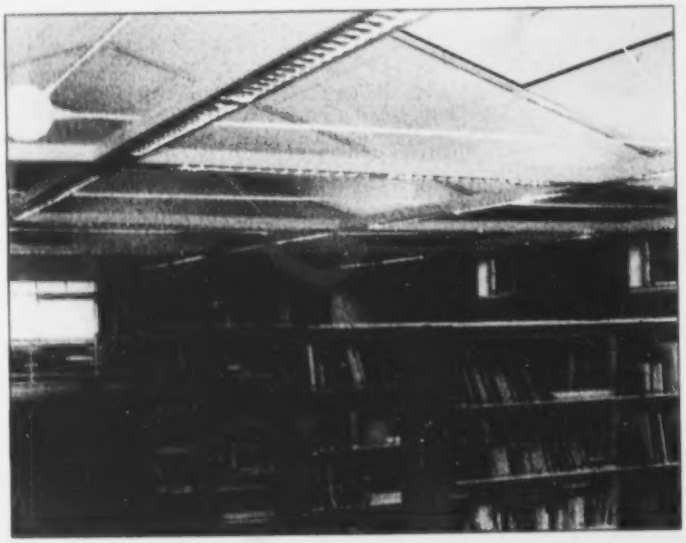

Figure 37: Library with bookstacks and study area. Netherhall School, Cambridge.

tables and browsing, but, due to its distribution characteristics, this arrangement is generally not ideal for vertical bookstacks as the illuminance level will usually be low, particularly for the bottom shelves. The vertical spines of books on the stacks need to be lit by special means, and using luminaires with an asymmetric distribution. Increased illuminance for the lower shelves can be obtained by the use of a light-coloured floor covering or by inclining them outwards. If it is not possible to provide ceiling mounted lighting directly related to the bookstacks due to the need for flexibility in bookstack position, it is suggested that a continuous line or lines of luminaires be used and positioned at right angles to the line of the bookstacks (Fig 38). The type of luminaire and its spacing will need to be selected to provide an even illuminance over the vertical spines of the books. More detailed information is given in CIBSE Lighting Guide: *Libraries*. Supplementary lighting should be provided for study tables and carrels and for the issue control desk. It may also be necessary to provide accent lighting for special displays.

Individual luminaires attached to the bookstacks or overhead luminaires in continuous rows at right angles to bookstacks, allows bookstacks to be moved.

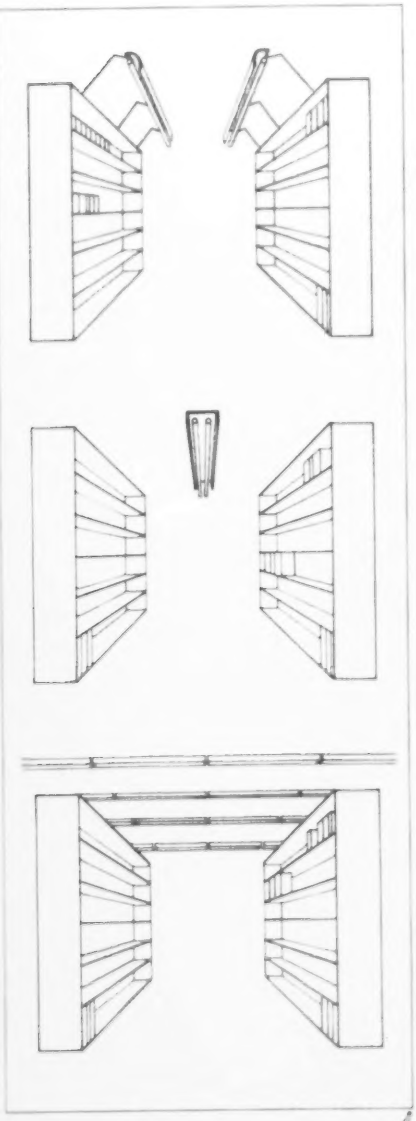

Figure 38: Lighting of bookstacks.

5.6 Art Rooms

The main requirement is good general lighting with artificial lighting at about the 500 lux level. There are frequent preferences for daylight from north-facing windows and for the availability of strong, directional lighting (Fig 39), particularly for sculpture and work involving texture. At times, the entry of sunlight can be an advantage, but windows associated with this entry must be fitted with adjustable sun-screening devices. Good rendering of colours is very important and lamps of CIE colour rendering group 1B should be used. Some additional flexible lighting for the display of work is desirable.

5.7 Sports Halls and Gymnasia

Although it is generally considered that daylight is beneficial in sports halls and gymnasia, windows and rooflights are frequently excluded because the sun and sky can cause both disability and discomfort glare to users who are moving quickly and often with an upward field of view. Reflected glare from shiny surfaces and particularly floors can also be a nuisance. If daylight apertures are provided, screening facilities for use when necessary should be available. To enhance the visual environment, it is suggested that luminaires with both upward and downward light should be utilised. There should be some control to keep glare to a

minimum and the light distribution should provide adequate light on vertical surfaces.

Lamps and luminaires should have wire guards or other impact-resistant protection.

Sports halls and gymnasia in schools are often used for non-sporting events including examinations, and therefore adequate consideration must be given to the lighting required for these events, some supplementary arrangement being installed if necessary (see section 5.8).

Because of the high mounting of the luminaires, satisfactory maintenance of the lighting installation will be difficult unless special provision in the form of access facilities is made. The use of long-life lamps in these circumstances should be examined.

Reference should be made to the CIBSE Lighting Guide LG4: *Sports*.

See also BRE General Information Report 35: *Daylighting for sports halls, Two case studies*.

Figure 39: Directional light in an art room.

Figure 40: Sports Hall at Oakmead School, Bournemouth, fitted with occupancy controls to switch on lights only in parts of the hall which are in use. [Photo: Ex-Or Limited]

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5.8 General Purpose Halls (Examination, assembly, performances and PE) and drama & dance studios

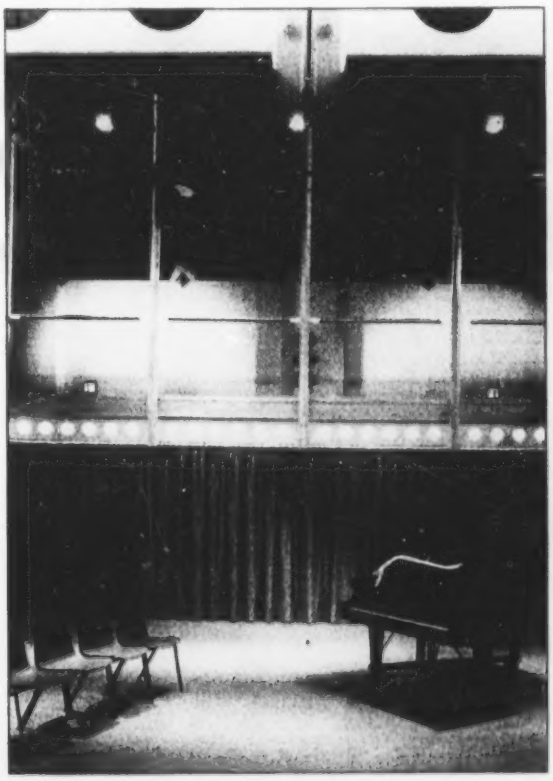
Very often there will be a need for a large space within the school to cater for activities ranging from examination to drama (Fig 41). The design will depend on the range of activities. Blackout will almost certainly be required as will a degree of flexibility in the lighting dependent on the range of uses envisaged and the budget. If the budget is limited a general lighting installation of luminaires which provide both upward and downward light should be used. The installation should meet the most stringent requirements in terms of activity, allowing the luminaires to be switched in groups to provide some flexibility. To complement this installation there should be a system of electric wiring which allows supplementary lighting equipment to be installed when needed. This may be of a stage lighting type which can be easily hired when required.

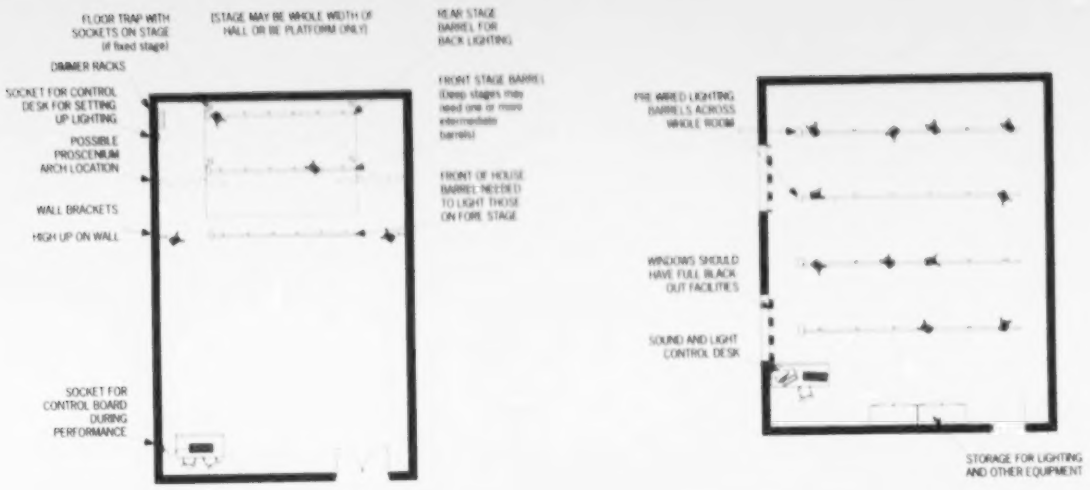
For teaching of GCSE and A-level Drama and theatre studies courses a good standard of stage and drama studio lighting will be required (see typical plans on the following page).

In halls likely to be used for concerts, theatrical and dance productions it may be necessary to arrange for an adaptable stage lighting system to be installed so that each event can be appropriately lit. Lighting barrels will need to be placed above the stage and in front of it so that stage lights can be positioned to light the faces of people performing on all areas of the stage. To achieve this, lighting needs to come from about 45° above and 45° to either side of any position on stage. This may involve using wall mounted brackets and lighting sockets. Where there is a fixed stage, floor-traps with stage lighting sockets should be located on either side for side-lighting dance, and for special effects lighting.

High level, wall mounted and stage sockets should all be wired back to a dimmer panel on one side of the stage.

Figure 41: left: Hall at Winton School, Andover. [Photo: Peter Cook] **Right:** Drama Space at Cambridge Regional College: daylight with black out. Bernard Stilwell Architects. [Photo: Jeremy Cockayne]




FLOOR TRAP WITH SOCKETS ON STAGE (if fixed stage)
(STAGE MAY BE WHOLE WIDTH OF HALL OR BE PLATFORM ONLY)
REAR STAGE BARREL FOR BACK LIGHTING
DIMMER RACKS
FRONT STAGE BARREL (Deep stages may need one or more intermediate barrels)
SOCKET FOR CONTROL DESK FOR SETTING UP LIGHTING
POSSIBLE PROSCENIUM ARCH LOCATION
FRONT OF HOUSE BARREL NEEDED TO LIGHT THOSE ON FORE STAGE
PRE WIRED LIGHTING BARRELS ACROSS WHOLE ROOM
WALL BRACKETS
HIGH UP ON WALL
WINDOWS SHOULD HAVE FULL BLACK OUT FACILITIES
SOUND AND LIGHT CONTROL DESK
SOCKET FOR CONTROL BOARD DURING PERFORMANCE
STORAGE FOR LIGHTING AND OTHER EQUIPMENT

Left: Stage lighting of general purpose hall

Right: Stage lighting of a drama studio

For larger halls there may be a need to provide a patch panel so that perhaps thirty individually wired sockets can be patched into eighteen or twenty-four dimmer ways. Control sockets for a mobile control desk should be positioned near dimmer racks for setting-up the stage lighting and at the back of the hall for controlling the lighting during a production.

Drama and dance studios are used primarily for the teaching of drama with some need for small dance class use. Whilst windows and daylight are of use, during lessons full blackout facilities will be needed on all windows.

Drama lessons are used to teach group skills, focusing on social and personal development, where general mood lighting across the whole studio is needed, as well as performance and stage craft skills, such as set and lighting design, where full theatre lighting is needed for performance use in any area of the room.

To achieve this there needs to be a basic structure of lighting points across the space for locating lights in any part of the room. Often the most convenient solution is to place a series of pre-wired lighting barrels at intervals across the width of the room. The lighting sockets should all be wired back to a dimmer panel and eighteen way control desk located in one corner of the room.

5.9 The Lighting of Chalkboards

It is essential to light chalkboards so that the material on them can be seen easily and comfortably by all members of the class. (The term chalkboard here includes blackboards used with chalk and whiteboards used with marker pens.) One of the frequent problems which occurs is caused by bright veiling reflections in the chalkboard of luminaires or windows. While it may be difficult to reduce sufficiently the luminance of these sources, the problem can be appreciably alleviated by having the chalkboard surface as matt as possible. A blackboard need not be black, but to retain a satisfactory contrast for the chalk writing,

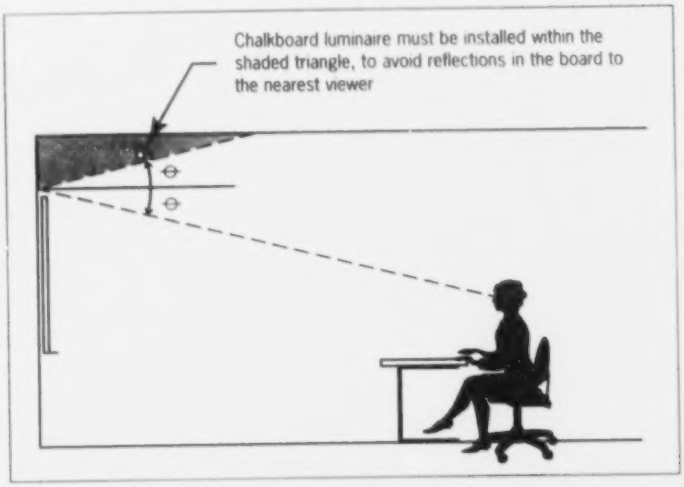

Chalkboard luminaire must be installed within the shaded triangle, to avoid reflections in the board to the nearest viewer

Figure 42: Chalkboard lighting

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its surface reflectance should not be greater than 0.1. A window in the same wall as a chalkboard should be avoided because there could be disability glare for the class producing severe difficulties in seeing the material on the chalkboard.

The chalkboard should be lit preferentially and a ceiling-mounted luminaire shielded from the direct view of the class is suitable (special luminaires are available commercially). The luminaire should be positioned as much as possible above and in front of the chalkboard but such that veiling reflections to the front of the class are avoided (Fig 42). The uniformity over the whole board surface should be as high as possible with little spill light around it. The recommended average illuminance over the surface is 500 lux, but this can be halved in the case of whiteboards.

5.10 Lighting and Visual Aids

Visual aids are commonly used for teaching, particularly film, slide and overhead projectors as well as television and video equipment. For the use of these teaching aids it is necessary to provide a lower level of lighting so that the presentation can be seen comfortably and clearly. For film and slide use, natural light must be excluded with suitable black-out facilities. Curtains and normal window blinds are usually not adequate; ideally black-out blinds which fit into slots surrounding the window reveals should be used. Sufficient light should be provided to enable notes to be taken during the presentation, and an illuminance over the seating areas within the range 15-30 lux is suitable. It is important that this should be provided by luminaires which have no lit element within the normal field of view. The reason for this is that if there are self-luminous elements within the field of view under these conditions, they will make the viewing of the presentation difficult. Also, light should not fall on to the projection screen and it should not be possible to see reflected images of luminaires or windows on the screen surface of television monitors. (See also Appendix 6 for details regarding lighting controls).

5.11 Lighting for pupils with visual and hearing impairments

Lighting and acoustic criteria are very important both to the visually impaired and to the hearing impaired. If one sensory channel is impaired more reliance is placed on the other channel. For example, the use of aural cues by the visually impaired and lip-reading by the hearing impaired. (See Building Bulletin 87[1] for advice on acoustic criteria for the hearing impaired).

The design of specialist accommodation for the visually impaired is beyond the scope of this document and expert advice should be sought[2,3].

The move towards integration of pupils with special educational needs into mainstream schools means that there are some measures that should be considered in the initial design brief of all schools. Whilst there is some special accommodation in mainstream schools, for the most part those with visual impairments are taught alongside their peers in ordinary classrooms. Therefore, all schools may have to cater for a continuum from pupils with quite minor visual impairments to those who are educationally blind. Although pupils with visual impairment are a minority they will be present in most sixth forms.

Many of the low cost or no cost measures can be applied to existing buildings such as the choice of decor (see Use of colour on page 43), tactile surfaces and types of luminaires. For a detailed description of possible measures see *Building Sight* published by the RNIB[4].

Other measures, such as providing or facilitating the use of visual aids can be considered as necessary. There is no single solution and what may assist one person may well not assist another. The following notes are offered as a general guide and should help in the majority of cases.

Types of visual impairment

It is useful for the designer to have a general understanding of the problems with which the student may have to deal. Visual impairments can be put into two

References:

(1) Building Bulletin 87: *Guidelines for Environmental Design in Schools*, DfEE, ISBN 0 11 271013 1, The Stationery Office 1997

(2) RNIB/GBDA Joint Mobility Unit, 224 Great Portland Street, London W1N 6AA
Tel: 0171 388 1266
Fax 0171 388 3160

(3) The Partially Sighted Society, 62 Salusbury Road, London NW6 6NS
Tel: 0171 372 1551
19/3/97 revision

(4) *Building Sight*, Peter Barker, Jon Barrick, Rod Wilson, RNIB, ISBN 011 701 993 3, HMSO 1995, £35

broad classifications resulting from a wide range of clinical conditions.

1. Field defects

Firstly, there are conditions where what is seen is seen clearly but the visual field is restricted. It may be that only the central part of the field is seen (tunnel vision) which can result from advanced glaucoma or some forms of retinitis pigmentosa. In this case mobility would be impaired although reading and the ability to do fine work would be largely unaffected.

The converse, loss of central vision, which might result from juvenile macular degeneration, would mean that movement could be made in safety but the ability to perform detailed tasks such as reading or sewing would be extremely difficult if not impossible.

Vision can be lost in 'patches', often resulting from diabetes, which may change in size and position with time. There can also be the loss of one half of the visual field, either the right or left side, or the upper or lower portion.

In all types of field defect the quantity of task illumination is generally unimportant providing normal recommendations are followed. Glare should be avoided (see section on acuity below). Decor can help rapid orientation (see section on use of colour below).

2. Acuity

The other main condition is a loss of acuity or a blurring of vision. The extent of the blurring varies widely from person to person and some may have to bring objects and print extremely close to their eyes to see best. There may also be an associated loss of colour vision.

Large print will, and higher illuminance may, be of assistance depending upon the cause of the loss of acuity. Many schools now have the facility to produce their own reading material and the use of a *sans serif* font of at least 14pt size can be a useful aid.

The effects of low acuity can be aggravated by glare, by which is meant any source of light or its reflection which is much brighter than the level to which the individual is adapted, and this should be avoided. A 'white' board on a dark coloured wall can be a glare source whereas a traditional 'blackboard' would not. Similarly, a view of a daylit scene through a window can be a disabling glare source.

Both loss of field and loss of acuity can occur together and, even when causes are similar, the particular difficulties which people with visual impairment experience, and their responses to light and other environmental features, can vary widely.

The use of higher than normal task illuminances can be of help to those whose acuity can be improved by the contraction of the iris, producing a greater depth of field. In some cases, however, such as those with central cornea opacities, the iris needs to be dilated so that the student sees 'around' the opacity. In such a case more light will aggravate, not relieve, the condition.

Positioning

In the past, many difficulties were caused by not realising the problems of the visually impaired. It should not be necessary to say that students with visual impairment should be seated where they can best see the work in progress. This may mean a position outside the normal arrangement, eg, immediately in front of the teacher or board.

It is also important that any visual aids are readily available for use. These may range from hand-held or stand mounted optical magnifiers to CCTV magnifiers. Local lighting may also be used as an aid (see Local task lighting on page 45).

It may also be necessary to allow the student to change position within the teaching space to accommodate access to an electrical supply, cope with excess daylight or use any other aid that is available.

Use of colour

A carefully designed colour scheme can be of great help in recognising and identifying a location and often more can be done with coloured surfaces to aid the visually impaired than with elaborate lighting installations. While in some spaces orientation may be established by

the furniture arrangement or by windows during daylight hours, in others it can be aided by the colour scheme. Whatever method is used, it is best adhered to throughout the building, ie, the different wall is always to the same side of the main exit from the space.

Some visual impairments involve a degree of colour blindness and it is important that contrast should be introduced in luminance and not just colour. For example, pale green and pale cream may be clearly distinguished by the normally sighted but be seen as a single shade of grey even by some pupils where an impairment has not been identified.

Contrast in the decor should be used to aid orientation within a space. The visually impaired primarily use sufficiently differentiated large surface areas to orientate themselves in a space particularly when it is unfamiliar. It may therefore be worth providing contrast between critical large surfaces such as ceiling, wall, floor and doors [5,6].

Special features such as stair nosings, handrails, door handles, the vertical edges of doors, electrical switches and control buttons need to be highlighted by a bigger colour difference to differentiate them from the surrounding large surface areas. For instance, using a darker colour for a handle which clearly contrasts with the surface of the door will indicate which way it swings. Coloured backplates to electrical socket outlets and light switches are available. They should also be located at constant heights throughout the building and be within easy reach.

Strong contrast is also needed for general obstacles particularly if they protrude at high level such as telephone booths, literature displays and coat and hat stands.

Finally, high gloss finishes should be used with care as they can appear as glare sources when they reflect bright lights such as sunlight. In general, eggshell finishes are to be preferred as some directional reflection is desirable rather than dead matt surfaces which may be difficult to place precisely.

Changes in the tactile qualities of surfaces can also be useful to reinforce visual contrasts. They are most important in schools for the blind.

Daylight

The fenestration will have been designed to facilitate the penetration of daylight which will be available for the majority of normal school hours. The window wall should be light in colour, to reduce contrast with the outdoor scene, and window reveals may be splayed to increase the apparent size of the glazing. It is important that students should be allowed to position themselves to use daylight to their advantage rather than be constrained to a formal classroom positioning.

Sunlight can be either a help or a hindrance, depending on the type of visual impairment, and some means of controlling the quantity should be provided. Traditionally this has been by means of blinds, either horizontal or vertical; both are successful but proper maintenance is necessary to ensure their continuing effectiveness.

It should be remembered that in the UK the greatest problems, both visual and thermal, are caused by low altitude sunlight at either end of the school day. Any solar shading devices, including those for rooflights must, therefore, be readily adjustable to cater for a range of conditions. Adjustment of solar shading should preferably be at the discretion of the students and not the teaching staff who may not fully appreciate the visual difficulties of the students.

Rooflights allow the ingress of sunlight over long periods therefore their design and positioning requires careful consideration to prevent obstruction of the sunlight by neighbouring buildings and to eliminate glare (see page 21).

Electric light

The control of glare from overhead lighting is particularly important to students with a visual impairment.

High frequency electronic ballasts for fluorescent lamps are to be preferred as they are more efficient, and they avoid the subliminal flicker that has been shown in scientific studies to increase headaches. Electronic ballasts also eliminate the

References:

(5) *A design guide for the use of colour and contrast to improve the built environment for visually impaired people*, ICI, 1997, £15, obtainable from Dulux Technical Group, ICI Paints, Wexham Road, Slough, SL2 5DS
Tel: 01753 691690

(6) *Colour, Contrast and Perception - Design Guidance for Internal Built Environments*, £14.95 from Wayne Collins Associates,
171-177 Great Portland Street, London, W1N 6NY.
Tel: 0171 470 0202

Further information from:
The University of Reading Research Group for Non-Handicapping Environments, Department of Construction Management and Engineering, P.O. Box 219, Whiteknights, Reading, RG6 6AW.
Tel: 0118 931 6734

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annoying visible flicker that conventionally ballasted lamps can demonstrate at the end of their life. If high frequency ballasts are used, consideration should be given to using a regulated version which can be dimmed to allow the illuminance level to be adjusted to suit the individual as well as to save energy. The additional cost for this is usually modest. It is important that the dimming circuit does not introduce additional flicker.

It is not normally economic to install more than the recommended illuminances on the off-chance that they will be useful some day to a hypothetical visually impaired student but additional illuminance can often be readily supplied when the need arises from local task lighting luminaires.

Summary

- Provide contrast in the decor to aid orientation and the location of doors, door-handles, switches and socket outlets, changes in direction in corridors, changes in floor level, stairs and steps.
- Avoid glare from windows, rooflights and luminaires either distant or immediately overhead.
- Provide facilities for the use of any visual aids, eg, magnifiers, telescopes, etc.
- Provide additional illumination by adjustable local task lighting as needed.

5.12 Local task lighting

Local task lighting is best provided from adjustable reading luminaires using compact fluorescent lamps. These have the advantage of long life and low energy consumption leading to low operating temperatures, thus avoiding thermal discomfort when used close to the task and the student.

Such luminaires can be positioned to provide the directional characteristics and illuminance best suited to the student. Luminaires should have a heavy base to aid stability or be clamped to the desk, and the heads should be adjustable in all planes so that they can be optimally positioned. Note that it is possible for a local lighting unit to cause glare to adjacent students but this can usually be avoided by careful siting.

A problem with local task lighting is the need for an electrical supply which, if only wall or floor mounted supply socket outlets are available, may introduce the hazards of trailing leads. If the student cannot be positioned close to a socket there is no simple solution to the problem. An overhead supply would enable leads to be dropped down to the desk position but it is hardly likely to be installed on a speculative basis. Battery powered reading lights are also a possibility.

5.13 Exterior Lighting

The exterior lighting of a school can serve three main functions. The first is concerned with ensuring that pedestrians and those travelling by car or bicycle, can see sufficiently well to enable them to move safely from the street to the entrance of the school. This will require a system of roadway/pathway lighting which will not only light these surfaces, but also provide sufficient vertical illuminance so that people and cars can be seen. It will be beneficial if the immediate surrounding areas also receive some light to define the general area. The school entrance will also need to be lit either internally or externally so that it can be clearly identified. If car parking is provided on the site this may also require a system of area lighting.

The illuminance chosen should reflect the location eg, urban or rural environment, and the level of risk from vandalism. The higher the risk, the higher the illuminance and the larger the area that should be covered.

The second function is concerned with the appearance and security of the school buildings at night (Fig 31). If a modicum of floodlighting can be provided it will show the importance of the school within the community. Two stage security lighting can be very effective. The first stage would be to provide a low level of background lighting, just above the ambient level, to deter opportunist vandals and to enhance the night-time appearance of the school. This is combined with second stage floodlighting of strategic areas such as entrances and

footpaths which is brought on by intruder detectors. High intensity tungsten halogen floodlights can be used for this second stage lighting. It should be remembered that security lighting is only of benefit where the building is under surveillance from neighbours or passers-by or by a CCTV system. The Department's Building Bulletin 78 *Security Lighting* and the new building bulletin to be published in 1999 *Security by Design* give further guidance on security lighting and CCTV systems. The choice of light source is most critical when designing for CCTV. The most energy efficient light source, low pressure sodium (SOX), is not suited to colour CCTV installations as it is mono-chromatic with little or no colour rendering properties and the narrow spectrum of the light does not match the spectral response of the cameras available. However an adequate picture may still be possible, particularly with a black and white camera.

The third function of exterior lighting is the lighting of sports facilities such as playing fields, tennis courts etc. Obviously the provision of this kind of lighting needs to be justified, and if by installing sports floodlighting the facilities can be used more extensively, perhaps the school can obtain revenue by hiring out these facilities, enabling some of the capital cost to be recovered.

It is not possible to describe here in detail the techniques of designing exterior lighting. The aim is to indicate possibilities which should be considered and if it is decided to include these forms of lighting then further information can be obtained from the CIBSE publications referring to outdoor lighting[7] and sports lighting.

Aspects of exterior lighting which need special attention are: the avoidance of light trespass, which is light causing a nuisance to people and dwellings in neighbouring areas; and light pollution which affects the local environment and atmosphere. Light trespass can be controlled by suitable selection of the light distribution of the luminaires to avoid 'spill light' and careful aiming of floodlights with the use of shields if necessary.

Generally the intensity of a floodlight beam diminishes away from the centre. In order to control glare from light it is often necessary to refer to an outer beam where the intensity of the light has fallen to 1/10th of the intensity of the main beam.

To prevent light pollution, luminaires must be chosen with a light distribution where all the light from this outer beam falls below an angle of 70° from the downward vertical. These are called full-cut lanterns and usually require flat glasses. (see Fig 43).

To achieve the correct uniformity in car parks or playing fields higher columns or closer spacing may be required.

Whilst there is no legislation concerning light pollution it has become a major planning issue with local authorities and some have adopted standards which define acceptable levels of light pollution[8]. Planning Departments often turn down proposals which would introduce major new light sources into areas without bright lights and would create substantial sky glow.

External lighting without automatic control is not energy efficient. Some form

Figure 43: Lighting of footpath with a luminaire which projects light in a downward direction. [Photo: P. Locker]

References:

7. CIBSE Lighting Guide LG6 *Outdoor Environment.*

8. The Institution of Lighting Engineers, *Guidance notes for the reduction of light pollution*, 1994, available from ILE, Lennox House, 9 Lawford Road, Rugby, Warwickshire, CV21 2DZ.

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of automatic control should be provided. Control can be by photocells and timeswitches or passive infra-red or other intruder detectors.

Although the purpose of exterior lighting equipment is to provide illumination at night, its daytime appearance should not be overlooked and it should complement the appearance of the building and its landscape.

5.14 Emergency Lighting

The purpose of emergency lighting is to provide sufficient illumination in the event of a failure of the electricity supply to the normal electric lighting to enable the building to be evacuated quickly and safely and to control securely processes, machinery, etc.

In schools, emergency lighting is only usually provided in areas not lit by daylight and those accessible to parents, teachers, pupils and the general public during the evenings. These include halls and drama spaces used for performances. Examples of places where emergency lighting might be considered are escape corridors, escape stairways and corridors without any windows. It should always be provided in sleeping accommodation. If necessary check escape routes during the hours of darkness to assess whether emergency lighting is required. In some cases, fluorescent marker lines may be an effective means of way marking. This reduces the level of light necessary to see the escape route.

It is recommended that for halls, gymnasia and other areas used by the public during the hours of darkness the emergency lighting should be of the maintained type which keeps the emergency lighting on at all material times.

On designated escape routes and fire escape stairs the installation can be of the non-maintained type which will only operate when the normal electric lighting fails, and will operate for not less than 1 hour's duration.

Where part of the premises is licensed it will be necessary to seek the advice and guidance of the Local Fire Authority.

The installation should reveal safe passageways out of the building together with the fire alarm call points, the fire fighting equipment, escape signs and any permanent hazards along the escape routes such as changes of direction or stairs.

Further detailed guidance is given in the CIBSE Technical Memorandum TM12: *Emergency Lighting* 1986 and in the British Standard Code of Practice for Emergency Lighting, BS 5266: Part 1: 1988. The latter is to be replaced by EN 1838, EN 50172 and the European Signs Directive which is already current. These include details regarding levels of illuminance, illuminance uniformity and specific details on escape signs. The following points (in EN 1838) should be noted.

- For escape route lighting and open-area (anti-panic) lighting the emergency lighting shall reach 50% of the required illuminance within five seconds and 100% within 60 seconds.
- The minimum value for the colour rendering index (Ra) of the light source shall be 40.

These criteria will generally be met by standard, self contained tungsten or fluorescent luminaires.

The primary requirement of an emergency lighting system is that of safety. However, there will be considerable visual benefits from taking this system into account when the normal electric lighting is being planned, because it may be possible to integrate the two installations. Some luminaires are available which can incorporate the emergency lighting as well as the normal lighting: alternatively luminaires can be specially modified to do this. The designer should be aware that any luminaire with a CE mark that is specifically modified must have the original mark removed and the luminaire retested and a new CE mark applied.

The servicing of a building continues to require more and more equipment, which without a proper integrated approach, results in visual 'clutter'. Emergency lighting equipment is one possible cause of this if not properly considered early in the design process.

Section 6: Check-list for lighting design

The purpose of this publication is to help the architect and the lighting designer to create a successfully lit school environment, an environment that is successful in terms of operation and appearance. Since this requires the consideration of a number of interlocking elements of building design, it is important that the designer considers the implications of each element both individually and holistically. Because of this complexity it is stressed that the designer should pay attention to all aspects of the information provided in the body of this publication and that the following check-list is used towards the end of the design process to ensure that nothing has been overlooked.

The numbers associated with each element of the check-list refer to the sections of the publication where further information can be obtained.

6.1 Task/Activity Lighting - 2.1

Examine how the space will be used and in particular the tasks and activities that will be undertaken. For this, consider the following:

Task illuminance (lux or daylight factor) - 3.1, 3.2, 4.1, 4.1.1 & 4.2
Task illuminance distribution/uniformity - 4.1 & 4.2
Discomfort glare (sun, sky & electric lighting) - 4.1.3, 4.2.1 & Appendix.5
Reflected glare (sun, sky & electric lighting) - 4.1.3, 4.2.1 & 4.2.3
Disability glare (sun, sky & electric lighting) - 4.1.3, 4.1.4 & 4.2.1
Lamp colour rendering (CIE colour rendering index) - 4.2.5 & Appendix.3
Lamp flicker - 4.2.2
Glare, colour and contrast for visually and hearing impaired pupils - 5.11

6.2 Lighting for Visual Amenity - 2.2

Determine the appearance of the lighting. Consider the following:

Light pattern - 3.1, 3.2, 4.1, 4.1.2 & 4.2.4
Subjective lightness - 3.1 & 3.2
Lamp colour appearance - 4.2.5 & Appendix.3
Discomfort glare - 3.1 & Appendix.5
Disability glare - 3.1
Lamp flicker - 4.2.2 & 5.4
Exterior/Interior view - 4.1.5

6.3 Lighting and Architectural Integration - 2.3

Ensure that the lighting equipment, together with its performance, forms an integrated part of the whole design. Consider the following:

Windows/rooflights - 3.1
Natural light design/pattern - 3.1
Luminaire/s - 3.2
Electric lighting installation - 3.2
Integration of natural and electric lighting - 4.3
Lighting controls - Appendix.6

6.4 Lighting and Energy Efficiency - 2.4

Check that the lighting installation, both natural and electric, utilises energy effectively. Consider the following:

Natural lighting design (windows/rooflights) - 3.1 & 4.1
Lamp type/s (efficacy lm/w) - 3.2, 4.2.5 & Appendix.3

Luminaire type/s - 3.2, 4.2.5 & Appendix.5
Electric lighting controls - Appendix.6
Integrating electric light with daylight - 3.3 & 4.3

6.5 Lighting Maintenance - 2.5

Poor maintenance of the lighting installation, both natural and electric, will reduce visual quality as well as waste money and energy. Consider the following:

Degree of environmental cleanliness/dirtiness
Cleaning and redecoration programme - 4.1 & 4.2
Lamp life and lamp replacement - Appendix.3
Disposal of used lamps - Appendix.7
Luminaire type/s - 4.2.5 & Appendix.5

6.6 Lighting Costs - 2.6

Lighting constitutes a relatively small part of the capital cost of a school, but none-the-less, it is an important element of design. Consider the following.

Capital cost of the lighting installation
Running costs of lighting equipment

6.7 Exterior and Emergency Lighting

These two special topics may not apply to all schools but a positive decision needs to be made regarding their use -5.13 & 5.14

Appendix 1: School Premises Regulations and DfEE Constructional Standards for new school buildings.

The Regulations which apply to both new and existing school buildings are the Education (School Premises) Regulations, 1996.[1]

For new school buildings, Building Bulletin 87[2] is the recommended environmental standard quoted in the DfEE Constructional Standards for School Buildings in England.

Schools that are subject to the DfEE Constructional Standards[3] are exempt from the procedures of the Building Regulations, but the Constructional Standards quote the Approved Documents to the Building Regulations in many cases. For example, in the case of fire the Constructional Standards quote Aproved Document B *Fire Safety* plus the DfEE vaiations given in the Constructional Standards.

The following points from the Building Regulations Part L (July 1995), Conservation of Fuel & Power[4] are summarised for information.

Part L requires lighting installations to satisfy two basic criteria:

- the light sources and their circuits should be of the energy efficient type; and
- the lighting installations must be controlled.

Guidance is given on how to achieve both these criteria, with alternative methods for calculation.

To satisfy the energy efficiency criteria requires that either 95% of the electric lighting load uses sources such as fluorescent tubes, compact fluorescent lamps or high pressure discharge lamps, or alternatively, the average circuit efficiency should be greater than 50 lumens/watt.

Exceptions are permitted, such as display areas or areas where a less efficient source would be more appropriate.

To satisfy the criteria of control requires switches to be placed locally. Arrangements can be made for central control, provided the central control point is manned or under the control of a responsible person.

It should be noted that both the CIBSE and DfEE have opted for a higher circuit luminous efficacy of 65 lumens/watt as an average, rather than the 50 lumens/watt as set out in the Building Regulations. However the method of calculating the value remains the same.

It is recommended that the Building Regulations requirements for lighting control are followed as being a sensible approach to Energy Conservation, but with the higher efficacy of 65 lumens/watt.

Construction Design and Management Regulations 1994 (CDM Regulations)

The CDM regulations apply to most new school building projects except for minor refurbishment work. They make it the responsibility of the designer to inform the client that he is required to appoint a Planning Supervisor to oversee the Health and Safety aspects of both the design and the construction. The designer must consider the Health and Safety implications of his design and input into the Health and Safety Plan and the Health and Safety File. For lighting installations, this means that it is the responsibility of the designer to ensure that the luminaires can be operated and maintained in safety. Means for relamping areas such as staircases, gymnasia, halls, external lighting etc, should be allowed for and where necessary agreed.

References:

1. Education (School Premises) Regulations 1996, Statutory Instrument 1996 No.360, available from The Stationery Office.

2. Building Bulletin 87: *Guidelines for Environmental Design in Schools (Revision of Design Note 17)*, 1997. The Stationery Office, ISBN 0 11 271013 1.

3. DfEE Constructional Standards available from Architects and Building Branch, DfEE, Caxton House, 6-12 Tothill Street, London, SW1H 9NF.
Tel: 0171 273 6237
Fax: 0171 273 6762

4. Approved Document L (Conservation of fuel and power) in support of the Building Regulations, Department of the Environment and Welsh Office, HMSO 1995, ISBN 0 11 7529338, £11.

Appendix 2: Lighting and Health

From time to time reports emerge which suggest that lighting may be a possible cause for concern within the working environment. In the past, these have ranged from a cause of headaches and eye strain to a possible cause of skin cancer. Not surprisingly the lighting profession takes these reports very seriously and endeavours to investigate the claims to ensure that the lighting it recommends is perfectly safe. It is not appropriate to describe here in detail the results of the various studies but to explain the general understanding at present.

One common area of concern is that of unseen radiation from fluorescent lamps, and in particular ultraviolet radiation: these produce considerably less than that produced by the sun. It is considered by those who have studied this topic that the risk from radiation is extremely small indeed and is thought unlikely to be a hazard.

Another potential problem is that of glare and flicker. It has been known for some time that these conditions can be the cause of visual discomfort which can impair vision, reduce visual performance and in some people cause headaches and eye strain. These temporary afflictions can be avoided by the use of high frequency ballasts. These topics have been considered elsewhere in this publication and here the importance of avoiding problems by good lighting design is stressed.

Some recent research[1,2] has shown that approximately 14% of the population are susceptible to eyestrain and headaches caused by 50Hz fluorescent lighting and that this reduces to about 7% with high frequency fluorescent lighting.

Epilepsy is sometimes triggered by low frequency flashes of light by which can occur with strobe lights, with some compact fluorescent lamps at ignition, or more generally with discharge lamps at the end of their life. Flicker at less than 4 flashes per second is unlikely to be a problem. 50Hz fluorescent lighting has not been shown to be a trigger for epilepsy.

There have been in recent times a number of studies related to 'sick building syndrome'. These studies found it extremely difficult to determine the exact cause of a particular problem, but it is interesting to note that problems rarely occurred in buildings with windows which provided people with both views out and natural ventilation. There seems to be little doubt that windows are a considerable benefit to an environment. It is suggested therefore that daylighting and natural ventilation should be a positive feature in school design.

Other studies have shown that people prefer lighting which creates a 'light' interior with a non-uniform light pattern. There is currently no evidence that this form of lighting improves health, but if people prefer it, the feeling of 'well being' which is created can only be beneficial.

The remaining subject to be considered here is that of the use of Polychlorinated Biphenyls (PCBs). Until 1976 this material was used in capacitors as part of some fluorescent lamp control circuits. Since that time manufacturers have moved to other materials. In 1986 Government Regulations prohibited the sale of PCBs in small capacitors for lighting equipment, but in existing installations they may continue in use - assuming they are in a serviceable state. After a period of use, some PCBs may leak from the capacitor, but the amounts involved are very small. However contact with the body should be avoided and for handling leaky equipment it is essential to use suitable gloves. Appropriate measures for disposal should also be taken.

In this Appendix an attempt has been made to indicate the present understanding of lighting and health, as it affects the school designer. It is felt that if the guidance presented in this publication is adhered to, then it is likely that a well-lit environment will be produced with risks to health avoided.

References:

1. *Modulation of light from fluorescent lamps*, Wilkins A.J. & Clark. C., Lighting Research and Technology **22** (2) 103-109, 1990, CIBSE.

2. *Fluorescent lighting, headaches and eyestrain*, Wilkins A.J., Nimmo-Smith I., Slater A.I., & Bedocs L., Lighting Research and Technology **21** (1) 11-18, 1989, CIBSE.

Appendix 3: Lamps

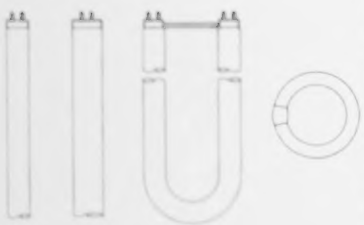
This appendix has been included to provide designers with an overview of the performance of a range of lamp types which could be used in schools. The information is presented mainly to help the designer make a first selection and it is assumed that manufacturers' data will be used for design purposes.

The data on pages 54 and 55 includes information on lamp efficacy, lamp life and colour performance together with the run-up and re-strike characteristics, and dimming capabilities.

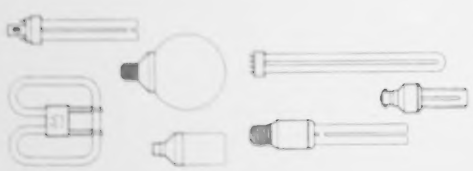
Appendix 3a: Lamp Types

General lighting service (GLS), Reflector (R) and (PAR), tungsten filament lamps
Advantages:
Point sources: Excellent colour rendering: Warm colour appearance; Dimmable
Cheap (GLS only, Reflector and PAR lamps are relatively expensive);
Instant start;
No Control gear required.
Disadvantages:
Short Life; Low efficacy; Sensitive to voltage variations and vibrations (any structural borne vibrations which shake the filament will reduce life, consider Rough Service lamps.)

Low and Mains Voltage Tungsten Halogen Lamps
Linear and Capsule TH (K), Reflector TH (M)
Advantages:
Point source; Excellent colour rendering; Warm colour appearance; Dimmable (Hard fired dimmer required); Instant start; range of wattages, sizes, and beam angles.
Disadvantages:
Low efficacy; low voltage 12 volt lamps require a transformer; Relatively expensive (compared to GLS); Sensitive to voltage variations and vibrations (any structural borne vibrations which shake the filament will reduce life, consider Rough Service Lamps).



Low Pressure Mercury Discharge Tubular Fluorescent Lamps (MCF)
Advantages:
Linear lamp, with some exceptions (circular, U shape not widely used – old technology); High Efficacy; Various colour appearances, Cheap; Long life; T12 - Halophosphate old technology 38mm tube, less efficient than - T8 - 26mm lamps Triphosphor, Generally better colour rendering than T12, new generation have low mercury content and low output depreciation. T5 - Triphosphor smaller lamp diameter 16mm tube, highest efficacy. All run off High Frequency Control gear, T12 & T8 will also run off Standard and low loss wire wound ballasts. Dimmable circuits are available for most types of fluorescent lamps.
Disadvantages:
Diffuse source; standard lengths; Control gear required; T5 only works on HF gear which is expensive.



Low Power Compact Fluorescent Lamps (SL, PL, 2D, 2L)
Advantages:
Smaller size than linear fluorescent; Some lamps dimmable; High efficacy; Long life; Relatively Cheap; some sizes can be used as direct tungsten lamp replacements (complete with control gear). High frequency gear available for higher wattage lamps (greater than 2x13w).
Disadvantages:
Diffuse source; Requires control gear; most circuits run at low power factor; tube wall very bright, can cause glare.

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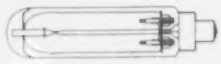
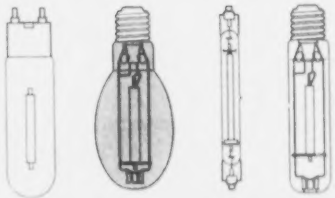
Appendix 3b: Lamp Types



Low Pressure Sodium Lamp (SOX)

Advantages:
Very High efficacy; long Life; relatively cheap; various wattages.

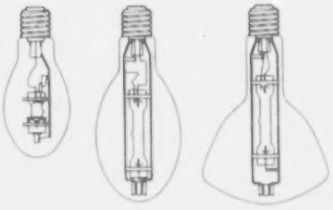
Disadvantages:
Mono-chromatic (yellow) light; no colour rendering; requires control gear. Run-up time required to reach full output.



High Pressure Sodium (SONDL)

Advantages:
High efficacy; Long life except "white" SON.

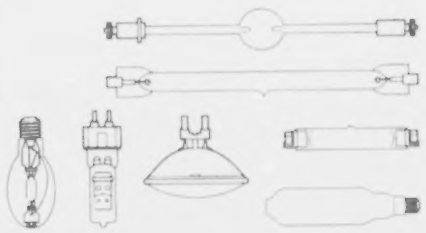
Disadvantages:
Effect of light source can be oppressive when used in an interior, except "white" SON; poor to average colour rendering except "white" SON which is good; colour appearance is warm (golden white); Requires control gear; requires run-up time.



High Pressure Mercury Vapour (MBF)

Advantages:
Long life; various wattages; De luxe versions average to good colour rendering; relatively cheap.

Disadvantages:
Generally poor to average colour rendering; poor efficacy; requires control gear; requires run-up time. Blue-green white light.



High Pressure Metal Halide Lamps (MBI, MBIF)

Advantages:
High efficacy; good colour rendering; warm/intermediate/cold colour appearance versions available; average to long life depending on wattage. Ceramic arc versions - good colour stability, longer life.

Disadvantages:
Some lamps change colour through life; high UV output-source needs glass cover; failure unpredictable; No British Standard. Requires control gear; requires run-up time. Ceramic arc versions - more expensive.

Induction Lamp

Advantages:
Very long life (except reflector lamp which is long life); low pressure lamp; good colour rendering; no flicker; virtually maintenance free.

Disadvantages:
Limited range; high electromagnetic radiation generated, requiring careful use; small lumen packages; diffuse source.

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Appendix 3: Lamps

Appendix 3c: Lamp data

Lamp type	Colour Rendering group/Colour Temperature, K (see Note 3)	Efficacy (approximate) Lumens/Lamp Watt (see Note 2)	Typical lamp life (hours)	Typical range of lamp power rating (wattage)	Control gear required	Lamp start-up time (Approx)	Lamp re-strike time (see Note 4)
Tungsten							
Mains (230V) GLS and reflector	1A/2700K	8–12	1000	15–1000	No	Instant	Instant
PAR	1A/2700K	10–12	2000	80–500	No	Instant	Instant
Tungsten halogen	1A/2900K	10–18	2000	50–100	No	Instant	Instant
Linear tungsten halogen	1A/2900K	14–22	2000	60–2000	No	Instant	Instant
Low voltage (12V) tungsten halogen	1A/3000K	12–25	3000–5000	5–100	Transformer	Instant	Instant
Fluorescent							
T12 (Halophosphate)	2/3000–5000K	60–80	7500	20–125	Yes	1–3 secs	1–3 secs
T8 (Triphosphor)	1A,1B/3000–6000K	60–95	7500–15,000	18–70	Yes	1–3 secs	1–3 secs
T5	1B/3000–4000K	95–110	10,000–15,000	14–50	Yes	1–3 secs	1–3 secs
Circular	2/3000–5000K	30–50	7500	22–60	Yes	1–3 secs	1–2 secs
Compact	1B/3000–6000K	43–83	7,000–10,000	5–55	Yes	1–3 secs	1–3 secs
Low pressure Sodium (SOX)	None	100–190	12,000–16,000	18–180	Yes	8-12 mins	Prompt <55w 10 mins >90w
High pressure Sodium (SON)							
Standard	4/2000	65–140	16,000–20,000	50–1000	Yes	1.5-6 mins	>1 min
De luxe	2/2200	75–90	12,000–16,000	150–400	Yes	5–6 mins	>1 min
White	1B/2500	35–50	5,000–10,000	35–100	Yes	5–6 mins	>30 secs
Mercury Vapour (MBF)							
Standard	3/4000	40–60	24,000-29,000	50–1000	Yes	2–5 mins	4–7 mins
De Luxe	2/3400	40–60	24,000-29,000	50–400	Yes	2–5 mins	4–7 mins
Metal halide (MBI)							
Single ended	1B,2/3000–4200	60–68	6000	70–150	Yes	3–6 mins	6–10 mins
Double ended	1B,2/3000–4200	68–75	6000	70–250	Yes	3–6 mins	6–10 mins
Tubular/elliptical	1A,2/4000–6000	70–80	6000–15000	70–1000	Yes	3–6 mins	6–20 mins
Ceramic arc tube	1B/3000	70–75	6000–8000	35–150	Yes	3–6 mins	6–10 mins
Induction							
Standard	1B/3000–4000	70	60,000	55–85	Yes	Prompt	Prompt
Reflector	1B/3000	47	10,000	23	Built in	Prompt	Prompt

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Notes to Appendix 3: Lamps

Note 1: The tabular data provide an indication of lamp performance: for exact data, information from manufacturers should be consulted.

Note 2: The power consumption of the control gear associated with discharge lamps should be included in estimating the efficacy of the installation: values vary and should be obtained from the manufacturer.

Note 3: See tables on the right for colour rendering groups and correlated colour temperature classes as defined by CIE.

Note 4: The re-strike time after an interruption to the electrical supply. 'Prompt' re-strike is not instantaneous but barely noticeable. Instant re-strike is available for all double ended high intensity discharge lamps using special high voltage ignitors, but they are too expensive for general use and do not affect the lamp start-up time.

Colour rendering groups	CIE general colour rendering index (R_a)	Typical application
1A	$Ra \geq 90$	Wherever accurate colour matching is required, eg, colour printing inspection
1B	$80 \leq R_a < 90$	Wherever accurate colour judgements are necessary and/or good colour rendering is required for reasons of appearance, eg, shops and other commercial premises.
2	$60 \leq R_a < 80$	Wherever moderate colour rendering is required.
3	$40 \leq R_a < 60$	Wherever colour rendering is of little significance but marked distortion of colour is unacceptable.
4	$20 \leq R_a < 40$	Wherever colour rendering is of no importance at all and marked distortion of colour is acceptable.

Correlated Colour Temperature (CCT)	CCT Class
CCT ≤ 3300 K	Warm
3300 K < CCT ≤ 5300K	Intermediate*
5300 K < CCT	Cold

* This class covers a large range of correlated colour temperatures. Experience in the UK suggests that light sources with correlated colour temperatures approaching the 5300 K end of the range will usually be considered to have a 'cool' colour appearance.

Appendix 4: Control gear

All discharge lamps require control gear to limit the current taken by the lamp it controls. There are various types of control gear which effect the overall performance of a lamp.

Control gear for Fluorescent lamps

Standard control gear consists of a basic unit with relatively high losses and harmonic components. Unless specified otherwise most luminaires will be supplied with this gear.

Low loss gear is slightly more expensive but generally the losses are half those of standard gear. The physical size allows it to be installed in most luminaires. For energy efficiency this is the minimum standard which should be adopted.

Super low loss gear is more expensive than low loss gear with roughly half the losses but the physical size is larger making it difficult to use in most luminaires.

High frequency gear is electronic gear. It is lighter and has the lowest electrical losses of all the conventional types of gear. It is much more expensive than conventional (wire wound) gear. It can be supplied in dimming form (more expensive still).

There is no simple payback advantage for this type of gear, at present. The life of the gear (not yet proven) is thought to be

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less than conventional gear and it is more susceptible to high temperatures (50-60°C).

Other advantages apart from low power losses are: it is flicker free; it reduces risks of epileptic fits; and it has a 'soft' start (increases lamp life).

There are two types of high frequency circuits, analogue and digital. Digital is more expensive but provides smoother dimming whilst analogue circuits provide step dimming. The choice will depend on the degree of control required.

Electronic starters. There are a number of canister type electronic starters available which provide a 'soft' start. These are slightly more expensive than a standard glow switch starter but when these electronic starters are combined with low loss gear many of the features of the high frequency circuit are provided but at a much lower capital cost.

Control gear for high pressure discharge lamps. Most lamps require their own dedicated control gear for efficient operation. However, there are some high pressure sodium lamps which will operate on mercury vapour lamp control gear. These are special lamps designed to be used as replacement sources for mercury lamps.

Metal Halide lamps. Most metal halide lamps require an ignitor which produces a 5kV pulse to start the lamp. It is essential to keep the ignitor close to the lamp, unless special high voltage cable is used when the ignitor can be remotely mounted. At the end of their life metal halide lamps can cycle and eventually may rectify. These conditions can be annoying and dangerous. It is advisable to specify the use of timed ignitors which will shut the circuit down before any damage can be done.

Mercury Vapour lamps. Power switches are available for some circuits which allows the lamp to run at reduced output and reduced power. This could be useful for areas where lighting is required during unoccupied times, or for security lighting when the lamps could be run all night at reduced consumption.

Sodium lamps. A similar power switch is available for some high pressure sodium lamp circuits.

Appendix 5: Luminaires

This appendix provides designers with an overview of the performance of a range of luminaire types so that simple comparisons can be made. The information is intended to help the designer make a first selection and that manufacturers' data will be used for design purposes.

The first data sheet is concerned with luminaires used in a regular array. Information is included on suitable lamp types, light output and distribution, luminaire mounting and spacing, utilisation factors and glare indices. The likely distribution of light within a space is also included.

The second sheet is concerned with luminaires used individually: in addition to lamp types, some general information is provided and a variety of data is available from manufacturers.

Appendix 5: Luminaires generally used in regular arrays: Typical characteristics

LUMINAIRE TYPE		SUITABLE LAMP TYPES	DISTRIBUTION / MOUNTING	NOMINAL SPACING/ HEIGHT RATIO	LIGHT OUTPUT RATIO	RANGE OF UTILISATION FACTOR (0.3 0.4 0.5 0.6 0.7 0.8; SL – LH)	RANGE OF GLARE INDEX (25 22 19 16 13 10; LL / SH)	LIGHT DISTRIBUTION WITHIN SPACE	COMMENTS
MODULAR	DIFFUSER	MCF	SEMI-DIRECT; S,P	1.75	0.75	SL – LH	LL / SH		
	PRISMATIC BASE		DIRECT; R,S,P	1.5	0.6	SL – LH	LL / SH		
	PRISMATIC CONTROLLER		SEMI-DIRECT; S,P	1.75	0.8	SL – LH	LL / SH		
	TRANSVERSE LOUVRE		SEMI-DIRECT; S,P	1.75	0.7	SL – LH	LL / SH		
LINEAR	LOW BRIGHTNESS REFLECTOR WITH TRANSVERSE LOUVRE	* SL PL 2D 2L	DIRECT; R,S,P	1.75	0.7	SL – LH	LL / SH		Some versions may be suitable for use in display screen equipment (DSE) areas
	DIRECT/INDIRECT		DIRECT-INDIRECT; P	1.25	0.6	SL – LH	LL / SH		
	WHITE TROUGH REFLECTOR		DIRECT; S,P	1.75	0.8	SL – LH	LL / SH		Useful for workstations. Some versions available with upward light slots & wire guards
	PERFORATED SCREEN REFLECTORS		DIRECT; R,S,P	1.70	0.73	SL – LH	LL / SH		Suitable for all areas including display screen equipment (DSE) areas
DOWNLIGHT		ALL except MCF	DIRECT; R,S,P	0.5 – 1.25	0.4 – 0.8	SL – LH	LL / SH		Extensive range available
HIGH BAY REFLECTOR		MBF MBI MBIF SONDL	DIRECT; S,P	0.75 – 1.75	0.8	SL – LH	LL / SH		Useful for sports halls. Some versions available with prismatic glass reflectors to provide upward light

R = RECESSED
S = SURFACE
P = PENDANT

SPACING/HEIGHT RATIO = S/h

SL = SMALL LOW REFLECTANCE ROOMS
LH = LARGE HIGH REFLECTANCE ROOMS
LL = LARGE LOW REFLECTANCE ROOMS
SH = SMALL HIGH REFLECTANCE ROOMS

LIGHT
MEDIUM
DARK

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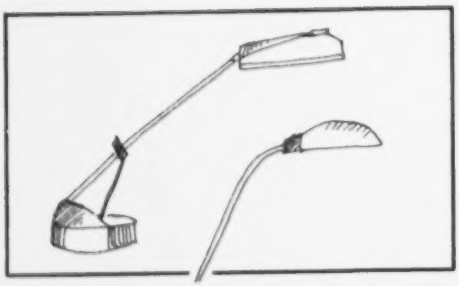
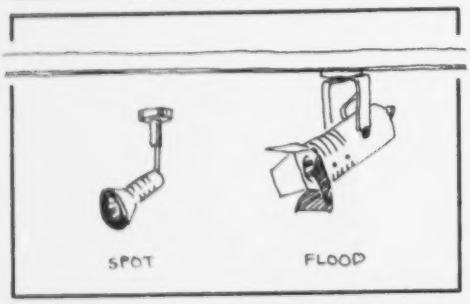


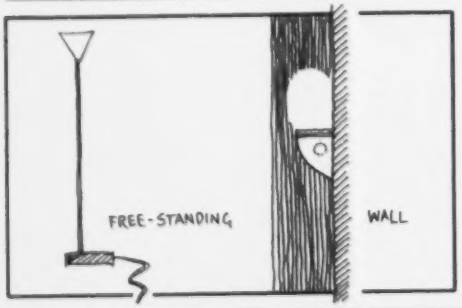
TASK/LOCAL LUMINAIRES
Often fitted with an integral dimmer and transformer. Some luminaires which are generally used in regular arrays (pages 57–58) can also be used individually for localised lighting.

GLS R TH(K) TH(M) MCF SL PL 2D 2L



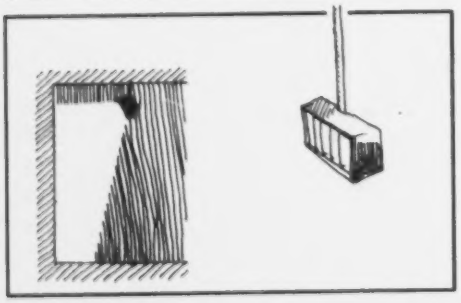
ACCENT & DISPLAY LUMINAIRES (SPOTLIGHTS & FLOODLIGHTS)
Generally wall, ceiling or track-mounted in either mains or low-voltage versions. Total beam widths are as follows: pencil(<10°); narrow (10-25°); medium (25-40°); wide (>40°).

GLS PAR TH(K) TH(M) SL PL 2D 2L MBI



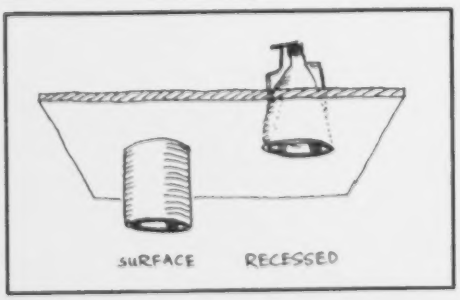
UPLIGHT LUMINAIRES
Available in free-standing and wall-mounted versions and a variety of light distributions. Occasionally used in regular arrays.

GLS TH(K) MCF SL PL 2D 2L MBI MBIF SONDL



WALL-WASHING LUMINAIRES
Used to emphasise vertical surfaces.

GLS TH(K) MCF PL 2L MBI



DOWNLIGHT LUMINAIRES
Available in recessed or surface-mounted versions. Often used in regular arrays.

GLS PAR R TH(K) TH(M) SL PL 2D 2L
MBF MBI MBIF SONDL

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Appendix 6: Lighting Controls

The lighting controls of an installation, ie, the switches, dimmers, etc, are an important part of a lighting design and need careful attention if the installation is to be convenient to operate and energy efficient. If the light switches are placed near the entry/exit point from general circulation, this is convenient, but the switches need to operate the luminaires relative to the distribution of daylight, ie, it should be possible to switch off the luminaires which are near the window, whilst keeping the lights on at the back of the room. In the first instance the switching of the lighting installation should be planned both to accommodate the convenience of the users and to allow the electric lighting to be switched to complement the daylight distribution. The arrangement of the switches on the switch plate also needs to be considered if the users are to operate the lighting with the minimum of inconvenience.

In many schools, the electric lighting is usually on longer than is necessary. Often the lighting is switched on first thing in the morning, perhaps by the cleaners or the first person to arrive, and because it is then overlooked it is left on all day until the last person leaves in the evening. This occurs, even though for a considerable part of the day, natural light would be sufficient to light the space and is a waste of energy and money. There are a wide range of automatic lighting control systems available, some of which are complex, and therefore too expensive for the typical school situation.

Time-switch controls

One system which is relatively inexpensive and which is likely to produce considerable energy savings, is a time-operated switch which will switch off all or some of the luminaires at a time in the day when it is likely that there will be sufficient daylight present. It must however be possible to over-ride the time-switch at any time that the users feel it necessary to switch on all, or some of the lights. The automatic switch-off time will depend on the particular daylight design, but it would be convenient if it could occur at a natural break in the day, eg, the mid-morning or lunch-time break. If after the break there is sufficient daylight, then the electric lighting will remain off until the daylight level falls below an acceptable minimum. For this type of control it is necessary to have special devices in individual luminaires, or groups of luminaires, to allow them to be switched off by a momentary break in the electricity supply which is activated by the time-switch. There should also be switches which the user can operate to switch on the luminaires at any time that they are required.

Photocell controls

The next level of automatic lighting control is to use light responding switches or photocell controlled switches. These will switch off luminaires as the daylight reaches a required level. The lighting can then be switched on again by the user as required. The designer should assess the performance and cost effectiveness of these automatic control systems.

Occupancy Controls

Another type of lighting control is the occupancy sensor controlled switch. This is a device that responds to the occupancy of a room. It can be used to switch lights on as people enter the space or switch them off when a room is not being used. These types of controllers are appropriate in intermittently occupied rooms. They have been used to good effect in toilets and changing rooms, and in assembly halls and sports halls where energy savings of 25-30% and payback periods of 3 years or less are possible (Fig 40).

It should be noted that frequent switching of light sources can have a detrimental effect on the lamp life. Using high frequency gear or electronic soft starts for fluorescent circuits can help to prolong lamp life.

Dimmers

Dimmers, or lighting regulators, can be used to adjust light levels between full

light output and off or in the case of some fluorescent lamp circuits to approximately 10 or 20% of full light output. These controllers are useful in rooms where visual aids are to be used, eg, overhead, film and slide projectors. Here the lighting can be dimmed to reduce the lighting level so that the overhead, film or slides can be seen comfortably but with sufficient light to enable notes to be taken. Other situations which probably require dimming circuits are drama studios and general purpose halls if these are to be used for drama or other events. If a dimming circuit is to be included, it is important to use lamps which can be dimmed satisfactorily. These include incandescent, tungsten halogen and some fluorescent lamps including cold cathode types. For schools it would be inappropriate to use high pressure discharge lamps in places where dimming is required.

Drama studios and halls which are to be used for theatrical presentations also require stage lighting control equipment (see section 5.8). Stage lighting is of a specialist nature and the choice will depend on the sophistication required and it is suggested that the manufacturers are consulted.

In-Luminaire Controls

Luminaires are available which contain elements of automatic control which can be beneficial to the end user. The systems are relatively simple to use, are cheaper to install (as no switch is required at the door) but the luminaires are more expensive.

These controls vary from a simple on/off device, presence or absence detectors, through to more sophisticated units which can be set to provide a maintained illuminance, daylight linked to allow for daylight by dimming, up to individual control by means of a hand held override unit.

This method of control is probably only going to be worthwhile where daylight linking and the maintenance of a set illuminance are going to be adopted as a means of reducing the operating costs of the building.

It is unlikely that the more sophisticated type of control will produce a short payback period, but developments in electronics are such that these devices should be kept under close scrutiny.

Individual 'clip-on' light sensors can be used to help maintain a set illuminance. These can simply be attached to any luminaire with an analogue dimmable ballast.

Appendix 7: Disposal of used lamps

Fluorescent tubes, compact fluorescent lamps, high pressure mercury lamps, metal halide lamps and high pressure sodium lamps all contain mercury. The amount of mercury varies between about 5mg and 35mg depending on the manufacturer and the age of the lamp.

	Fluorescent tubes	Compact Fluorescent lamps	High Pressure mercury	Metal Halide	High Pressure Sodium	Low pressure sodium
Mercury milligrammes per lamp(mg)	20 - 35	20 - 35	20	30 - 45	10 - 20	0
Sodium milligrammes per lamp(mg)	0	0	0	3	5	400
Average weight of lamp (g)	200	200	100	150	300	300

Some of the mercury is absorbed into the glass, some is present in the phosphor layer and some is present as free mercury. Many older lamps also contain cadmium which is a known carcinogen. This needs to be considered during disposal. Lamps currently manufactured in Europe do not contain any cadmium.

Fluorescent tubes also contain rare earth metals such as antimony. However the main concern is mercury. It fulfils essential physical functions within the gas discharge and there is no substitute. The EC permissible limit for mercury is only one part per billion in drinking water. This gives an indication of its toxicity. It is worth remembering that mercury contained in fluorescent lamps is only a small part of the mercury released to the environment. The UK Lighting Industry Federation states that only 0.3% of the mercury entering the environment comes from lamps. Nevertheless the total amount of mercury contained in the world's annual production of lamps has been estimated at 75 tonnes.

The CIBSE *Interior lighting guide* appendix 5.11 *Environmental aspects of lighting* gives an analysis of the total amount of mercury released to the environment both by the production of the electricity used by the lamp and by the disposal of the waste lamp at the end of its life, for the different types of lamp. This shows that compact fluorescent lamps have the most mercury in the waste lamp per KWh of electricity produced. However, due to their inefficient use of electricity, ordinary filament lamps lead to a greater release of mercury to the environment, than any other type of lamp, although the waste lamp does not contain any mercury.

It is best from an environmental point of view to arrange for used lamps to be recycled by a specialist company. Sweden, Austria and America have been recycling used lamps to recover the mercury for many years and this facility is now available in the UK. Mercury presents a long term threat in the environment. Free mercury may be safely absorbed at first but in time can react to form mercury metal compounds which can be more dangerous.

The charge for recycling is currently between £0.25 - £0.50 per tube. The price reduces with increasing quantities of lamps, therefore it may be desirable to store used lamps until there are a sufficient number to benefit from a reduced rate. Some relamping contractors will arrange to recycle lamps as part of their contract. Alternatively schools can consult their waste disposal company about the method of disposal used and what facilities are available for recycling lamps. Some of the big waste disposal companies are now linked to the specialists who recycle lamps. Sites that recycle lamps containing mercury need a license to do so.

There are safety implications of storing used lamps on site and a school doing this has a duty of care to do it safely. If lamps are stored for more than one school a license to do this will be required from the local waste regulation authority.

Questions on disposal are usually directed to the Local Office of the Environment Agency which has responsibility for implementing the 1990 Environmental Protection Act and the 1996 Special Waste Regulations. Lamps from schools are not classified as Special Waste under the 1990 Environmental Protection Act. Waste from schools is classified as household waste and under

the 1996 Special Waste Regulations household waste, as defined by the EPA, cannot be Special Waste, unless it is asbestos or comes from a laboratory. In any event lamps containing mercury would not be classed as Special Waste unless they contained over 3% by weight of mercury, or they contained sodium as well as mercury. However, low pressure sodium lamps which have not been broken would be classed as Special Waste(unless they are present in household waste) due to the risk of the sodium igniting. The manufacturers instructions with each lamp contain the recommended safe method of storage and disposal. They can be broken in accordance with the manufacturers guidelines and doused with water to react with the sodium. The liquid can then be put down the drain and the glass fragments treated as ordinary waste.

The breaking of fluorescent tubes is a hazardous operation. However, small quantities of unbroken fluorescent tubes can be put into the normal domestic refuse. Where lamps are replaced in large quantities the used lamps must be treated as difficult waste and taken to a site licensed to handle them. Although it is permitted to dispose of used lamps to normal land fill sites they are becoming increasingly wary of taking waste containing mercury, and disposal via a specialist recycling company is preferable.

Lamp Breakage

When lamps have been removed from service the principal hazard is broken glass. Placing them in the packaging provided with the new lamps is one way of protecting them from accidental mechanical breakage or scratching, which could lead to glass fracture and possibly flying fragments. Special storage bins are available from lamp recycling companies. Where recycling is not possible and it is necessary to break lamps to reduce bulk, good housekeeping practice should be followed, ie, protective clothing including gloves should be worn, and preferably the operation should be in a well ventilated area or outdoors.

Many lamps are filled to pressures above or below atmospheric pressure and therefore care must be exercised in fracturing the lamp envelope. Whenever glass is broken it is a requirement of the Protection of the Eyes Regulations 1974 that eye protection must be worn.

Only the outer envelopes of high pressure discharge lamps should be broken. The inner arc tubes are strong and should be left intact as a container of the lamp constituents, eg, small quantities of mercury.

If there are large numbers of lamps to be broken, machines are available which break the glass while at the same time spraying the debris with water to prevent powder flying and to react any sodium if this type of lamp is being crushed. The advice of the local water supply company should be sought regarding the safe disposal of this water (Statutory Instrument SI 1156 must be observed). The purpose of this appendix is to show

Reference:
Statutory Instrument, 1989 No.1156, Water, England and Wales, *The Trade Effluents (Prescribed Processes and Substances) Regulations* 1989

Appendix 8: Examples of lighting design strategies

the development of lighting design decisions based on the criteria described in the body of the document. It does not give completed designs but shows the considerations and processes involved by means of illustrative examples. The solutions are not meant to be 'ideal', and should not be used for an actual project without checking that they are satisfactory for the particular situation. Every situation is different and the designer has to respond to the actual circumstances including the user requirements and to the interpretation of the constraints. The examples are not related specifically to either primary or secondary schools but are considered to be appropriate for either with some modifications to suit the particular case.

The first example (Appendix 8.1) explores the interaction between the building and its site. It examines the various factors which can influence the actual position of the building on the site and also the exact location of classrooms and other areas.

The second example (Appendix 8.2) considers a typical basic classroom unit of 2.7m height (floor to ceiling), and it is presumed that there is only one external wall. The basic daylighting performance is evaluated and it is then extended to consider how this might change by the addition of a rooflight or clerestory window at the back of the room. The electric lighting is then explored, for both function and appearance, in terms of supplementing the daylight when necessary and at night-time.

The third example (Appendix 8.3) considers a fairly typical two-storey atrium space. A number of glazing arrangements are investigated with regard to their daylighting performance both within the atrium and in adjoining rooms, and to other factors including visual contact with the outside. Three electric lighting schemes are examined and, as with the daylighting, maintenance of the component items is considered.

It is emphasised that these examples do not provide solutions to be followed in practice; they are illustrative examples to demonstrate strategic and other more detailed considerations concerned with lighting design for schools.

APPENDIX 8.1 SITE ANALYSIS

The orientation and position of a building on a site can affect the quantity and quality of light entering spaces, in addition to taking advantage of any pleasant view. The following diagrams show some of the influences on this positioning and indicate advantages and disadvantages in relation to a notional site. This bulletin is not concerned with the additional problems of access and noise intrusion, although these two factors also affect siting.

ORIENTATION

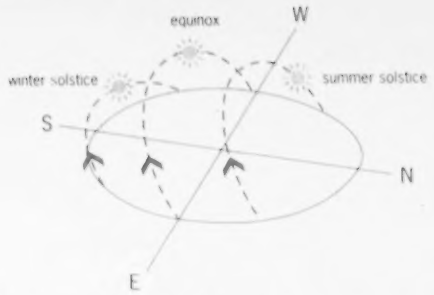
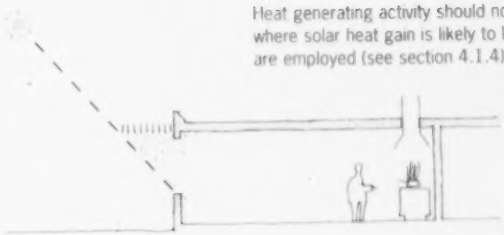


Diagram showing sun's path for summer & winter solstices and the equinoxes for approximately a latitude of 52°N (London)

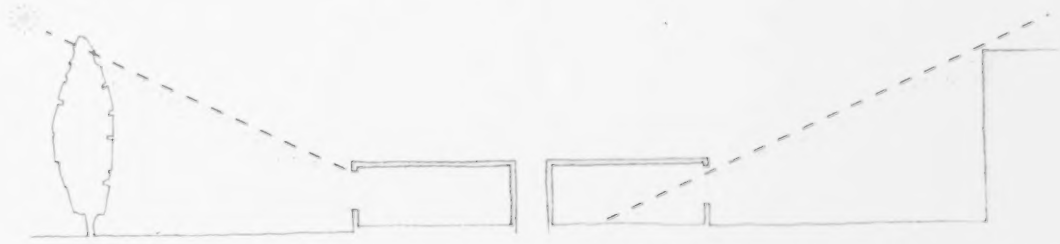
Diagram showing daylight orientation factors.
The luminance of the southern sky is greater than that of the northern sky (see section 4.1.1)

SOLAR GAIN

Heat generating activity should not be planned on that side of a building where solar heat gain is likely to be a problem unless protective measures are employed (see section 4.1.4)



OVERSHADOWING



Tall buildings and dense trees can screen from low angle sun

Tall buildings and dense trees can overshadow, reducing the amount and penetration of daylight

VIEW

Views provide considerable benefit (see section 4.1.5)

LIGHT TRESPASS

Night time lighting of playing areas can cause annoyance to neighbours. 'Spill light' and glare from floodlights should be minimised (See section 5.13).

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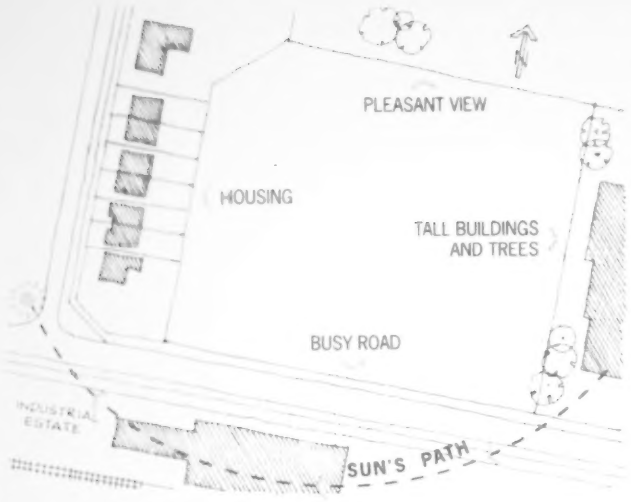

This figure represents a notional site with commonly occurring features:
neighbouring tall building and trees;
pleasant view;
busy road and view to industrial estate;
neighbouring housing.

For the purpose of the example, the north point has been placed to the top of the site.

The plan is not to scale.

The following diagrams indicate some advantages and disadvantages of placing a school in various positions on the site: for clarity the plan is over-simplified.

It will be seen that the best result must be a compromise after the various components have been considered.

DIAGRAM 'A' BUILDING ON NORTH OF SITE

	NORTH FACING CLASSROOMS	SOUTH FACING CLASSROOMS
ORIENTATION	low sky luminance	high sky luminance
SOLAR GAIN	none	risk of gain in summer
OVERSHADOWING	none	none
VIEW	very pleasant	less pleasant
LIGHT TRESPASS	a possibility	a possibility

DIAGRAM 'B' BUILDING ON EAST OF SITE

	EAST FACING CLASSROOMS	WEST FACING CLASSROOMS
ORIENTATION	medium sky luminance	medium sky luminance
SOLAR GAIN	little risk	little risk
OVERSHADOWING	In early morning from tall buildings	none
VIEW	less pleasant	pleasant
LIGHT TRESPASS	a probability	a probability

DIAGRAM 'C' BUILDING ON WEST OF SITE

	EAST FACING CLASSROOMS	WEST FACING CLASSROOMS
ORIENTATION	medium sky luminance	medium sky luminance
SOLAR GAIN	little risk	little risk
OVERSHADOWING	none	none
VIEW	pleasant	less pleasant
LIGHT TRESPASS	low possibility due to screening by school	low possibility due to screening by school

DIAGRAM 'D' BUILDING ON SOUTH OF SITE

	NORTH FACING CLASSROOMS	SOUTH FACING CLASSROOMS
ORIENTATION	low sky luminance	high sky luminance
SOLAR GAIN	none	risk of gain in summer
OVERSHADOWING	none	none
VIEW	very pleasant	least pleasant
LIGHT TRESPASS	a possibility	a possibility

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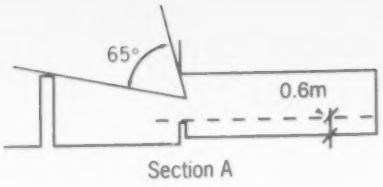
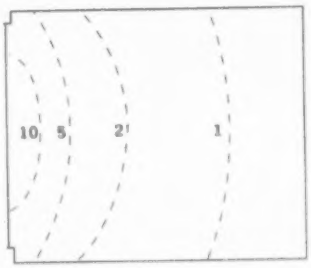
APPENDIX 8.2: A TYPICAL CLASSROOM

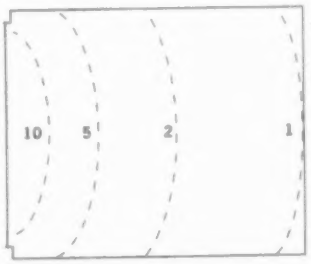
This worked example considers a typical classroom (8 x 6.5m) with a minimum height of 2.7m and an external wall 6.5 x 2.7m (Scheme A). The room is expected to be used for general teaching activities including reading, writing and craftwork. The classroom may have a formal teaching position together with pin-up boards to display student work. Alternatively, it may be used informally. The aim is for the classroom to be mainly daylit for most of the time and to have electric lighting to complement the natural light when necessary. At night-time the electric lighting will provide good seeing conditions for all but the most difficult tasks when supplementary task lighting can be employed. The following schematic exploration shows the development of possible lighting solutions together with the expected performance.



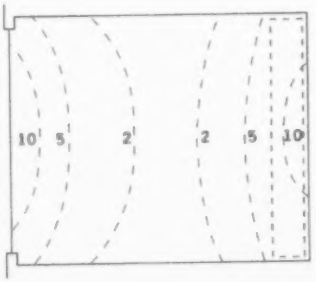
Section A



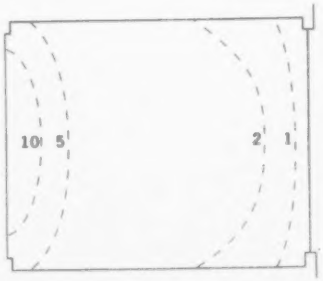
SCHEME A Figure 1



SCHEME A* Figure 2



SCHEME B Figure 3



SCHEME C Figure 4

INITIAL DAYLIGHTING STRATEGY

Consider a typical window (6 x 2m), SCHEME A, and its daylighting performance :

Average Daylight Factor $\overline{DF} = \frac{TW\Theta}{A(1-R^2)}$ where

T = glass transmittance, including maintenance factor (0.8 x 0.9 = 0.72)
W = glass area (12m²)
Θ = window sky acceptance angle (65°)
A = total room surface area (182.3m²)
R = area-weighted reflectance (0.45)
Values in brackets are those used for initial calculation.

$\overline{DF}$ = 3.9% Minimum DF = 1%

If double glazed (ie, T = 0.65 x 0.9 = 0.59) then
$\overline{DF}$ = 3.1% Minimum DF = 0.8% (Figure 1)

If most of external wall is glazed (ie, W = 16m²), SCHEME A*, then
$\overline{DF}$ = 5.2% (single glazing) Minimum DF = 1.25%
$\overline{DF}$ = 4.2% (double glazed) Minimum DF = 1% (Figure 2)

(Minimum Daylight Factor values found from point calculation method using the standard CIE overcast sky).
It can be seen that, even with a fully glazed wall, a $\overline{DF}$ of 5% (the minimum design objective for a 'well' daylit room) can only be achieved with single glazing which will encounter thermal problems.

DAYLIGHT ILLUMINANCE

The following table indicates the orientation-weighted Daylight Factors (see Table 4, page 17) required to provide various levels of daylight illuminance.
Note: orientation-weighted Daylight Factor = DF (CIE overcast sky) x orientation factor.

Unobstructed Illuminance lux	% of year for which illuminance is exceeded in UK	Orientation weighted daylight factors to achieve given lighting levels			
		100 lux	200 lux	300 lux	500 lux
5,000	84	2%	4%	6%	10%
10,000	68	1%	2%	3%	5%
15,000	50	0.67%	1.34%	2%	3.33%

ANALYSIS

The typical window investigated (12m²) will not provide sufficient daylight for the whole year. For approximately half the time electric lighting will be required - at least at the back of the room.
There are two possible solutions: a) increase daylighting by the addition of a rooflight or clerestory if possible and b) provide electric lighting to supplement daylight when required.
Two extended daylighting solutions have been investigated (Schemes B and C) and the likely performances are shown in the illustrations (Figures 3 and 4).

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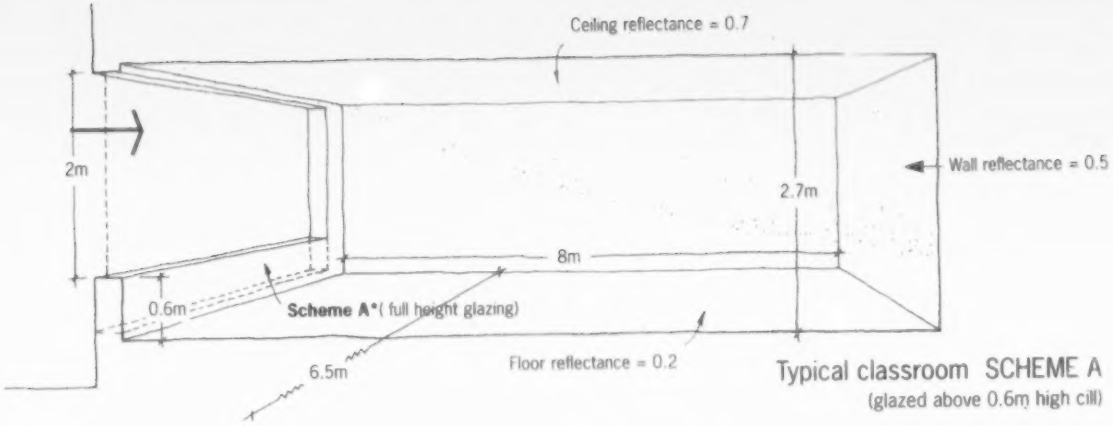
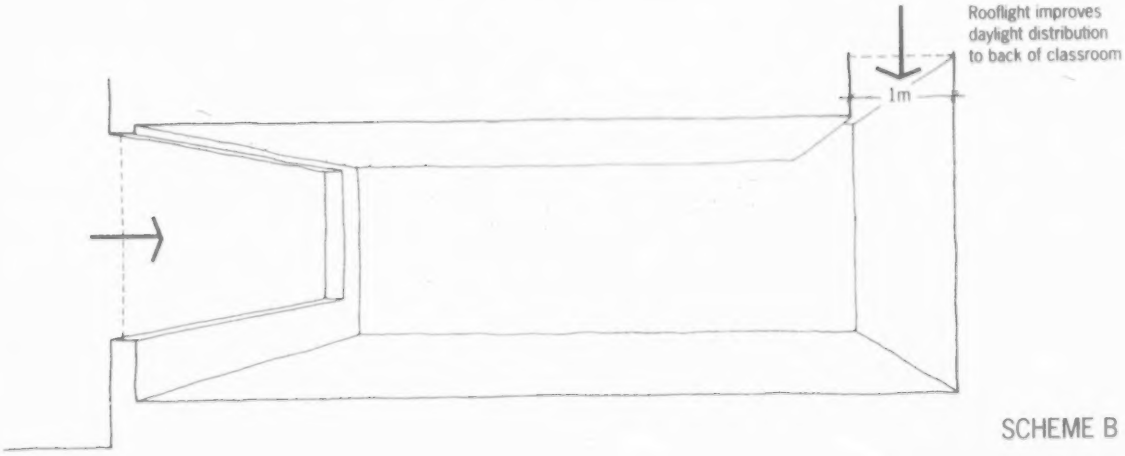
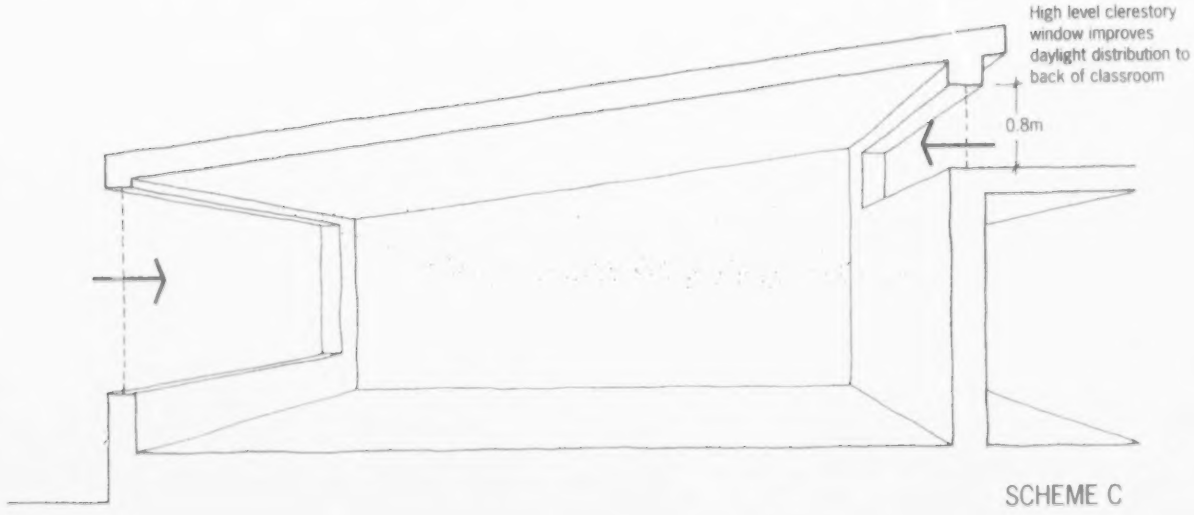


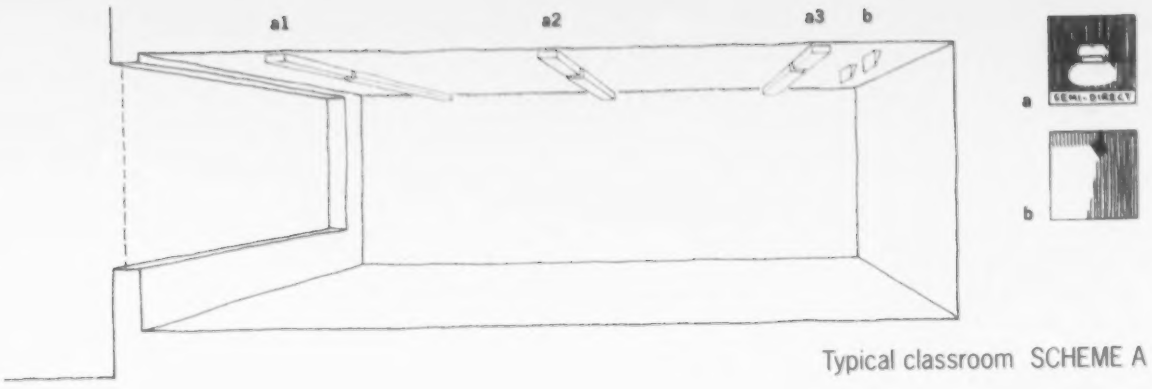
Typical classroom SCHEME A
(glazed above 0.6m high cill)



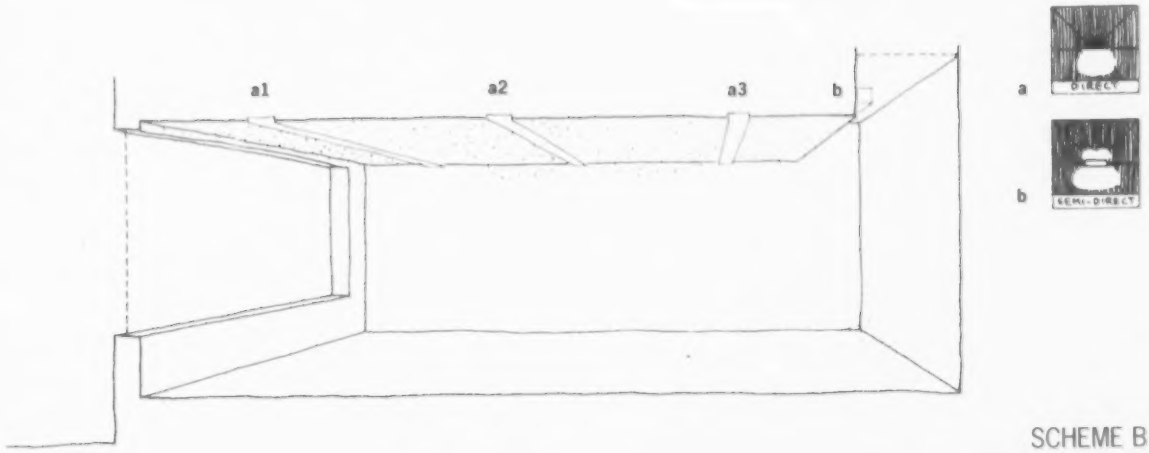
SCHEME B



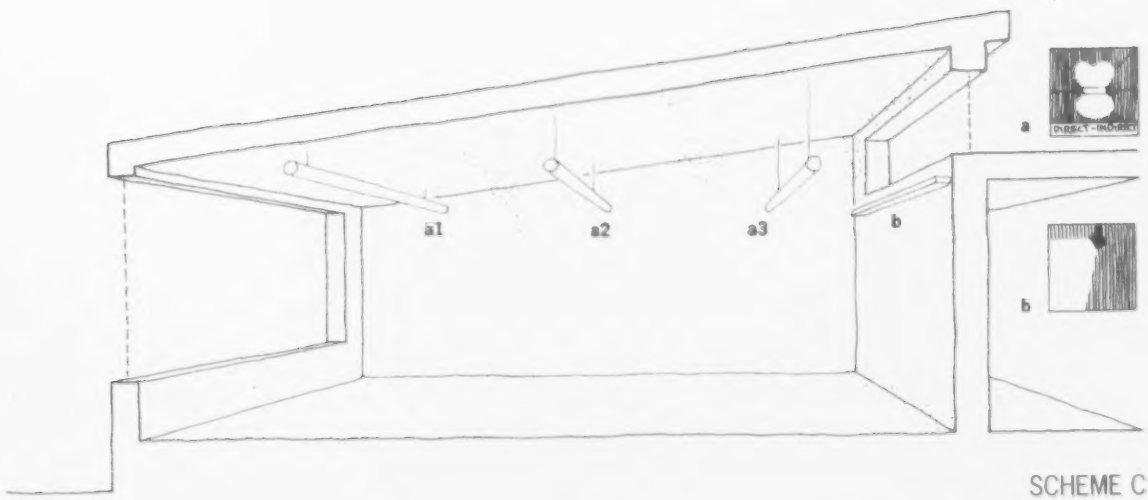
SCHEME C



Typical classroom SCHEME A



SCHEME B



SCHEME C

ELECTRIC LIGHTING

Assume a basic requirement for a Task Illuminance of 300lx with a horizontal plane uniformity of not less than 0.8 and a Limiting Glare Index of 19. Suggest using a regular array of 'Semi-Direct' distribution luminaires equipped with a single 1.5m 58w tri-phosphor lamp (Average Lamp Light Output = 5100lm) (Appendix 3).

Room Index = 1.8 (A measure of the proportions of a room. See CIBSE Code for Interior Lighting Section 4.5.3.2), Typical Utilisation Factor = 0.6 (Appendix 5), Maintenance Factor at end of one year = 0.86

$$\text{No. of luminaires} = \frac{\text{Illuminance} \times \text{Area}}{\text{Utilisation Factor} \times \text{Maintenance Factor} \times \text{Lamp Light Output}} = 6 \text{ luminaires}$$

With a 2x3 array, the maximum spacing = 6.5/2 = 3.25
Maximum Spacing to Mounting Height ratio = 3.25/1.95 = 1.7 (acceptable)
Glare Index = not greater than 19 (Appendix 5)

Luminaire layout as shown in illustration individually switched in rows a1, a2 and a3 parallel to the window. In addition to the regular array, a line of luminaires should be included to illuminate the back wall (Scheme A).

Variations on the basic proposal are shown for the schemes which utilise rooflights and clerestories (Schemes B and C). NOTE: FOR ACTUAL DESIGNS USE MANUFACTURERS' PHOTOMETRIC DATA

ENERGY EFFICIENCY

To ensure maximum energy efficiency without compromising the quality or visual effectiveness of the installation, consider the following:

- To optimise use of daylight install photocells or time-switches to turn electric lighting off when not required (possibly during mid-morning break). Also provide manual over-ride in classroom.
- Install lighting controls (switches) in a logical way to ensure only the luminaires required will be switched on.
- Consider using high frequency control gear to improve visual comfort and energy efficiency.
- Implement regular lighting maintenance programmes.

CONCLUSIONS

- The basic design with side windows only (window area 12m²) is likely to provide adequate natural light conditions for approximately half the year depending on window orientation (Scheme A).
- The windows will provide acceptable view out but window blinds may be necessary to obscure direct sunlight depending on the window orientation and external obstructions.
- When the natural light is insufficient this can be supplemented by luminaires at the back of the room.
- The regular array of luminaires will provide good working conditions over the whole horizontal plane with an acceptable comfort level. The luminaires which provide wall lighting at the back of the room will accent the wall display and enhance the visual appeal of the room (Scheme A).
- The two proposals with the addition of either a rooflight or clerestory window provide a higher level of daylight and hence a potential reduction in the use of electric lighting. They will also produce a better visual environment (Schemes B and C).
- The accent lighting aims to provide an additional visual focus. However, it is important that this equipment integrates with the design of the classroom. This also applies to the regular array of luminaires for the general lighting.

APPENDIX 8.3: AN ATRIUM

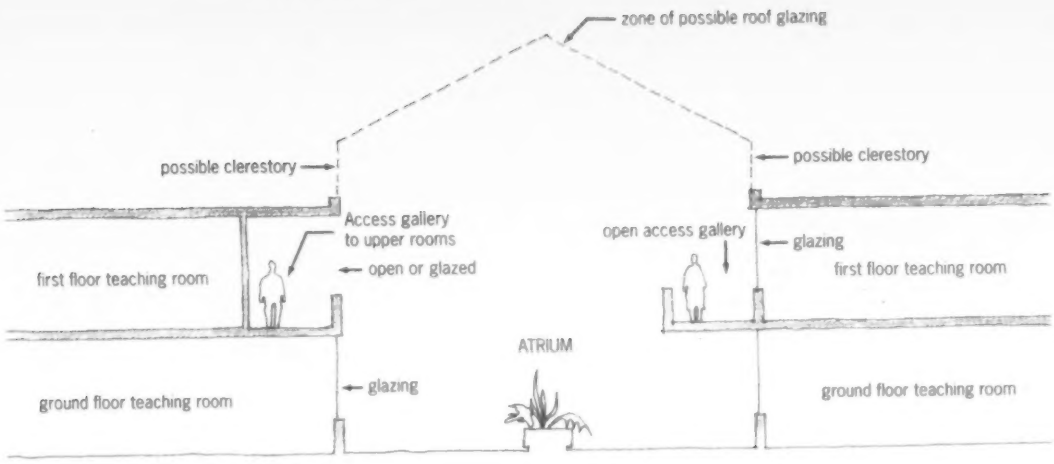


DIAGRAM SHOWING POSSIBLE SECTION THROUGH TYPICAL 2-STOREY SCHOOL ATRIUM

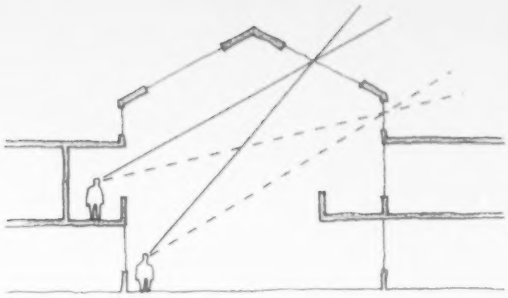
The space could to be used for school assembly, dining, general socialising and private or group study, in addition to circulation and display. It may be landscaped, using suitable plants, and can form a focal centre. Atria will be predominantly lit by daylight when available and they can contribute to the enhancement of the visual environment of surrounding areas, by providing a change of view, and by increasing daylight availability to the rear of teaching rooms which might otherwise be lit from one side only on their window wall.

There are some general factors to be taken into account when considering atrium design from the lighting point of view. For example - the level of light should neither be so high that adjoining spaces appear dim by comparison nor so low that the atrium itself appears under-lit when viewed from these spaces. In order to achieve a satisfactory distribution of light particularly in the lower areas of the space, it is important that the majority of surfaces, in particular those on the vertical plane, have a higher reflectance value. This should also include the floor and furniture. The orientation of the atrium glazing will be influential in relation to sun and sky glare, and solar gain. Clear glass is recommended in order to give a view out and to cut out sunlight diffusion which occurs with translucent materials. If solar control glass is used, consideration should be given to the possibility of colour distortion and the creation of an 'under-lit' effect. Sky luminance is another factor (see section 4.1.1).

Spaces of this type are often two storeys or more in height and provision for cleaning and maintenance of the glazing and luminaires is necessary.

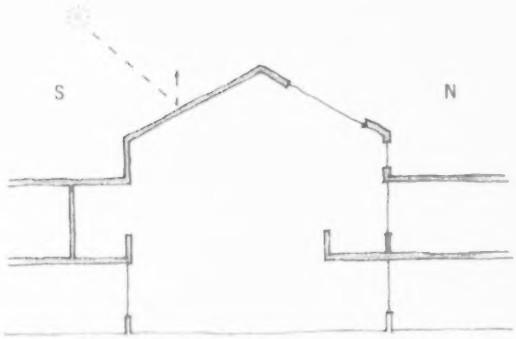
The additional problems of acoustic and thermal environments are not specifically dealt with here, although these factors will have to be considered in atrium design.

The following diagrams show some of the main factors to be considered.



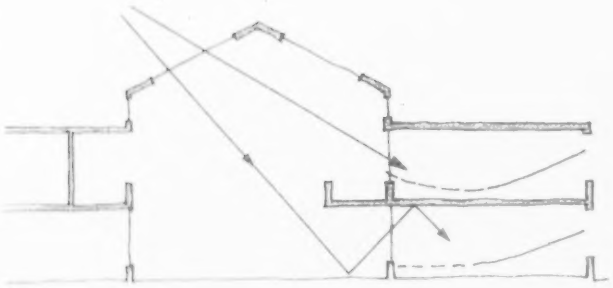
SKY GLARE

In top glazing, sky glare is likely to be more of a problem than in side glazing, because the luminance of the upper part of an overcast sky is greater than that of the lower. This can be ameliorated by ensuring that areas surrounding glazing are light in colour, and by the use of adjustable louvres or blinds.



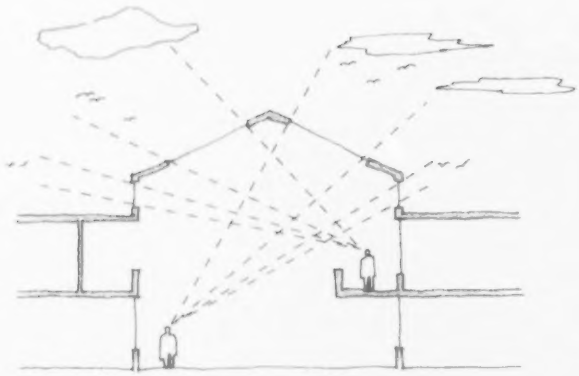
SUNLIGHT GLARE AND SOLAR GAIN

Sun glare and solar gain can be a problem which can be controlled by the use of adjustable louvres or blinds, and by appropriate orientation. The admission of some sunlight however will enliven the visual scene. In summer, solar gain will cause overheating unless controlled, whereas in winter it can contribute to the thermal environment.



SUPPLEMENTATION of DAYLIGHT to ADJOINING SPACES

The atrium can be used to make a contribution to the lighting of the part of an adjoining room furthest away from the window wall, by supplementing the daylight.



VISUAL CONTACT WITH EXTERIOR

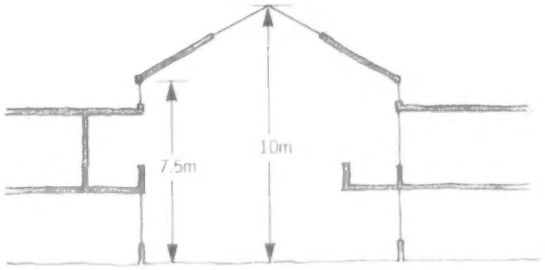
Visual contact with the exterior through the glazing is desirable and diffusing glass is not recommended.

DAYLIGHTING

The advantages and disadvantages of the following glazing arrangements are examined with respect to the factors discussed earlier. For the two basic forms an atrium of 15m x 10m in plan, with a height of 7.5m to the top of the wall and 10m to the ridge is considered. Double glazing is assumed, and the area-weighted reflectance of the interior surfaces is taken to be 0.4. It is considered that to achieve appropriate daylighting for a school atrium, a minimum average daylight factor of 7% should be provided.

ROOF GLAZING

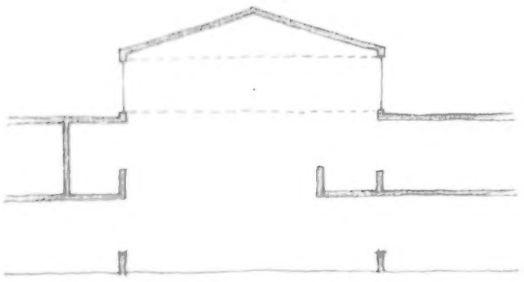
The area of roof glazing required to obtain an average daylight factor of 7% at the bottom of the atrium can be determined by adapting the calculation formula and method used in Appendix 8.2 for the classroom window glazing. A correction factor of 0.8 is applied for dirt on the glass.
In these circumstances the calculated area of glazing is approximately 55m^2 which could be obtained by a width of 2.1m either side of the ridge for the length of the atrium.



SKY GLARE	could be troublesome - precautions need to be taken
SUN	could be troublesome - precautions need to be taken
SUPPLEMENTATION	good for upper levels of adjoining rooms
VISUAL CONTACT	good

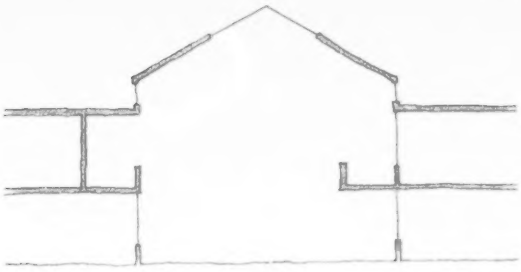
CLERESTORY

The area of clerestory required to obtain the same daylight level can be determined by a similar calculation to that used above. A correction factor of 0.9 is applied for dirt on the glass.
In these circumstances the area of glazing is approximately 100m^2 which would require a clerestory height of 2m for the full perimeter which may be difficult to achieve in practical terms.



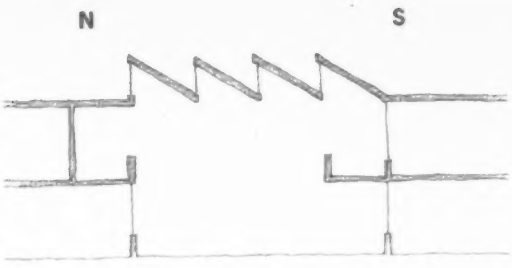
SKY GLARE	could be troublesome - precautions need to be taken
SUN	could be troublesome - precautions need to be taken
SUPPLEMENTATION	good
VISUAL CONTACT	good

COMBINED ROOF & CLERESTORY



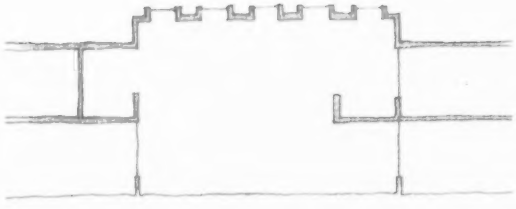
SKY GLARE	less troublesome - precautions need to be taken
SUN	less troublesome - precautions need to be taken
SUPPLEMENTATION	good for upper levels of adjoining rooms
VISUAL CONTACT	less good

'SAW-TOOTH' PROFILE



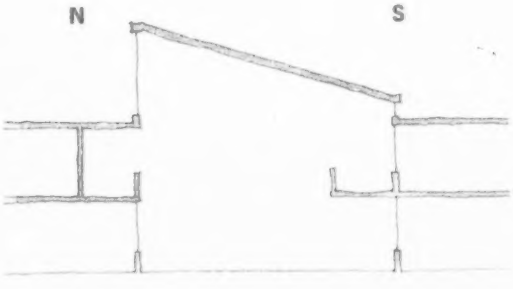
SKY GLARE	no problem
SUN	no problem
SUPPLEMENTATION	good for rooms on south side
VISUAL CONTACT	less good

LAY LIGHTS



SKY GLARE	not troublesome
SUN	not troublesome
SUPPLEMENTATION	poor
VISUAL CONTACT	limited

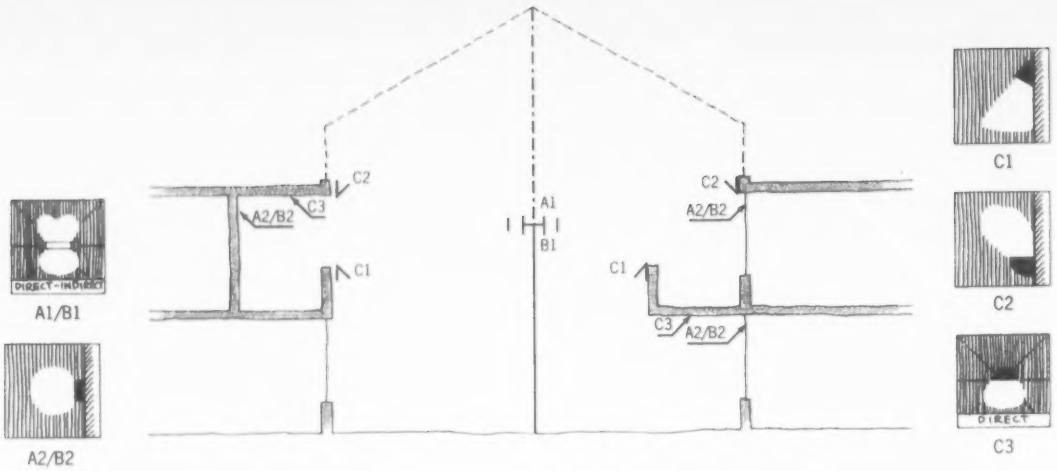
ASYMMETRIC PROFILE



SKY GLARE	less troublesome
SUN	not a serious problem
SUPPLEMENTATION	good for rooms on south side
VISUAL CONTACT	good for rooms on south side

Appendix 8.3: An atrium

ELECTRIC LIGHTING



It is considered that for the electric lighting to achieve the desired visual characteristics discussed earlier for a school atrium, a suitable arrangement would be to have a general installation with a direct/indirect light distribution providing an illuminance level of approximately 400 lux at the atrium floor, and this would be complemented by some form of accent lighting which could include highlighting displays, plants, etc. For this arrangement to be satisfactory, it is important, as for the daylighting situation, to ensure that the majority of surfaces, and in particular for the electric lighting, the underside of the roof, have a high reflectance value. In selecting the equipment, it is necessary to consider its ease of maintenance, including access to it for this purpose, so that its performance remains high.

Three schemes for the electric lighting installation are outlined below, with some calculation details for scheme A being given. The dimensions of the atrium space are as used for the daylighting study.

Scheme A. Suspended luminaires

For the main lighting, it is proposed to use high pressure metal halide lamps (MBIF): these have good colour rendering properties with a white colour appearance, high efficacy and long life. They would be housed in luminaires providing a 'Direct/Indirect' light distribution, at a mounting height of 5m above the floor. Using 400 watt MBIF lamps (average light output = 26,000 lumens), an estimated utilisation factor U.F. of 0.35 and a one year maintenance factor M.F. of 0.8:

$$\text{Number of luminaires} = \frac{\text{Illuminance} \times \text{Area}}{\text{Lamp light output} \times \text{U.F.} \times \text{M.F.}} = 8$$

A suitable arrangement would be to suspend the luminaires in pairs (A1) on the long axis of the atrium, an optical system providing an asymmetric downward light distribution, and the Glare Index restricted to be less than 19. A 'rise and fall' suspension system would facilitate maintenance.

Additional general lighting (A2) would be provided by wall, surface-mounted diffuser luminaires equipped with compact fluorescent lamps. (SL, PL, 2D, 2L) with some light on to the wall surface behind: these luminaires should be installed in circulation spaces.

Accent lighting would be formed by display screens employing low wattage tungsten halogen reflector lamps (TH(M)) which would be mounted on the screens.

Scheme B. Column-mounted luminaires

This arrangement is similar to that for Scheme A but with the pairs of luminaires for the metal halide lamps mounted on centrally installed columns at the same 5m height (B1). These columns at floor level would be within planting or seating areas, and if necessary be hinged at the base so that the luminaires could be lowered for maintenance.

The additional general lighting and the accent lighting would follow the pattern in Scheme A, but the lower part of the columns could now form the basis for the display lighting.

Scheme C. Perimeter-mounted luminaires

The direct component of the main lighting is provided by wall-mounted prismatic refractor luminaires incorporating a reflector (C1) and equipped with 250 watt high pressure mercury discharge tubular metal halide lamps (MBI). The indirect component utilises the same type of lamp installed in asymmetric reflector floodlights (C2), their light falling on the adjacent part of the underside of the roof. Recessed downlights (C3) using compact fluorescent lamps are used in this scheme to illuminate circulation spaces where there is a soffit. Wall mounted general lighting (A2) as in Scheme A, is used where there is no soffit. The display lighting would be the same as that mentioned in Scheme A for the screens.

It is important in the selection of all items of lighting equipment to ensure that there is good integration with the atrium design as a whole.

Actual photometric data provided by manufacturers for their luminaires should, of course, be used in any practical design.

GENERAL

When the various factors described in relation to sunlight, daylight and electric light are taken into account, a well-lit atrium space can contribute appreciably to the environment of a school, both by providing a visual centre and by complementing the view from surrounding areas.

Glossary

The definitions and explanations given in this glossary are based on British Standard 4727: Part 4: *Glossary of terms particular to lighting and colour*, and on the fourth edition of the *International Lighting Vocabulary* (CIE 17.4:1987) issued jointly by the Commission Internationale de L'Eclairage and the International Electrotechnical Commission. These documents should be consulted if more precise definitions are needed.

adaptation
The process which takes place as the human visual system adjusts itself to the brightness or the colour of the visual field.

average daylight factor
The spatial average of daylight factors over a reference plane or planes. (For design purposes in this document, it is the average over a horizontal working plane).

ballast
Current limiting device found in a luminaire.

CIE standard overcast sky
Completely overcast sky for which the ratio of its luminance L_θ at an angle of elevation θ above the horizon to the luminance L_z at the zenith is assumed to be given by
$L_\theta = L_z (1 + 2 \sin\theta)/3$

colour appearance
A term used of a light source. Objectively the colour of a truly white surface illuminated by the source. Subjectively, the degree of warmth or coolness associated with the source colour.

colour rendering
A general expression for the appearance of surface colours when illuminated by light from a given source compared, consciously or unconsciously, with their appearance under light from some reference source.

colour rendering index
A measure of the degree to which the colours of surfaces illuminated by a given light source conform to those of the same surfaces under a reference illuminant, suitable allowance having been made for the state of chromatic adaptation (see Appendix 3).

contrast
Subjectively this term describes the difference in appearance of two parts of a visual field seen simultaneously or successively. The difference may be one of brightness or colour or both.

correlated colour temperature
The temperature of a full radiator that emits radiation having a chromaticity nearest to that of the light source being considered. The unit is the kelvin, K. (see Appendix 3).

daylight factor
The illuminance received at a point indoors, from a sky of known or assumed luminance distribution, expressed as a percentage of the horizontal illuminance outdoors from an unobstructed hemisphere of the same sky. Direct sunlight is excluded from both values of illuminance. (daylight factor = sky component + externally reflected component + internally reflected component).

direct glare
Glare caused when excessively bright parts of the visual field are seen directly, eg, lamps which are inadequately shielded.

directional lighting
Lighting designed to illuminate an object or surface predominantly from some preferred direction.

disability glare
Glare which impairs the ability to see detail without necessarily causing visual discomfort.

discomfort glare
Glare which causes visual discomfort without necessarily impairing the ability to see detail.

downward light output ratio
The ratio of the total light output of a luminaire below the horizontal under stated practical conditions to that of the lamp or lamps under reference conditions.

externally reflected component of daylight factor
The illuminance received directly at a point indoors from a sky of known or assumed luminance distribution after reflection from external reflecting surfaces, expressed as a percentage of the horizontal illuminance outdoors from an unobstructed hemisphere of the same sky. Direct sunlight is excluded from both illuminances.

flicker
Impression of regular fluctuations of brightness or colour.

glare
The discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the general surroundings.

glare index
A numerical index calculated according to CIBSE Technical Memorandum TM 10. It enables the discomfort glare from lighting installations to be ranked in order of severity and the permissible limit of discomfort glare from an installation to be prescribed quantitively (Limiting Glare Index).

illuminance
The luminous flux density at a surface, ie, the luminous flux incident per unit area (lumens per square metre (lm/m^2) or lux). [This quantity was formerly known as the illumination value or illumination level.]

illumination
The process of lighting an object or surface.

internally reflected component of daylight factor
The illuminance received at a point indoors from a sky of known or assumed luminance distribution after reflection within the interior, expressed as a percentage of the horizontal illuminance outdoors from an unobstructed hemisphere of the same sky. Direct sunlight is excluded from both illuminances.

light output ratio
The ratio of the total light output of a luminaire under stated practical conditions to that of the lamp or lamps under reference conditions.

luminaire
An apparatus which controls the distribution of light given by a lamp or lamps and which includes all the components necessary for fixing and protecting the lamps and for connecting them to the supply circuit. Luminaire has superseded the term lighting fitting.

luminance
The physical measure of the stimulus which produces the sensation of brightness measured by the luminous intensity of the light emitted or reflected in a given direction from a surface element, divided by the area of the element in the same direction. The SI unit of luminance is the candela per square metre (cd/m^2).

luminous efficacy
The ratio of the luminous flux emitted by a lamp to the power consumed by the lamp (lm/W), this term is known as lumens/lamp watt. When the power consumed by control gear is taken into account, this term is sometimes known as lamp circuit luminous efficacy and is expressed in lumens/circuit watt.

luminous flux
Quantity of light emitted by a source, or received by a surface. The SI unit of luminous flux is the lumen (lm).

luminous intensity
A quantity which describes the power of a source or illuminated surface to emit light in a given direction. It is the luminous flux emitted in a very narrow cone

containing the given direction divided by the solid angle of the cone. The SI unit of luminous intensity is the candela (cd) equal to one lumen per steradian.

maintained illuminance
The minimum illuminance which should be provided at all times through the life of an installation: it takes into account cleaning schedules for room surfaces and luminaires, and lamp output depreciation with time.

no-sky line
The locus of points in the reference plane delineating the area from which no sky can be seen.

reflectance
The ratio of the luminous flux reflected from a surface to the luminous flux incident on it.

reflected glare
A term used to describe various visual effects, including reduction of contrast, discomfort and distraction, produced by the reflection of light sources or other bright areas in glossy or smooth surfaces.

sky component of daylight factor
Ratio of that part of the daylight illuminance at a point on a given plane which is received directly through glazing from a sky of assumed or known luminance distribution to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky. Direct sunlight is excluded from both illuminances. Usually expressed as a percentage.

spacing/height ratio
This ratio describes the distance between luminaire centres in relation to their height above the working plane.

specularity
The specular quality of a reflection as in a mirror, as opposed to a diffuse reflection from a matt surface in which the luminous flux comes from many directions none of which predominates.

standard maintained illuminance
The maintained illuminance recommended for the assumed standard conditions of the application.

transmittance
The ratio of luminous flux transmitted by a material to the incident luminous flux.

uniformity ratio
The ratio of the minimum illuminance to the average illuminance over a given area, usually a horizontal working plane.
OR
The ratio of the minimum daylight factor to the average daylight factor over a given area, usually a horizontal working plane.

upward light output ratio
The ratio of the total light output of a luminaire above the horizontal under stated practical conditions to that of the lamp or lamps under reference conditions.

utilisation factor
The proportion of the luminous flux emitted by the lamps which reaches the working plane both directly and by reflection.

Notes

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